UC-NRLF
$B 259 565

THE

SEWERAGE ENGINEER'S NOTE-BOOK,

BEING

STANDARD NOTES ON SEWER FORMULÆ AND SEWERAGE CALCULATIONS.

BY

ALBERT WOLLHEIM, ASSOC.M.INST.C.E.

SECOND (REVISED) EDITION.

LONDON:
THE ST. BRIDE'S PRESS, LIMITED,
24 BRIDE LANE AND 13 NEW STREET HILL,
FLEET STREET, E.C.

PRICE THREE SHILLINGS AND SIXPENCE, NETT.

REESE LIBRARY
OF THE
UNIVERSITY OF CALIFORNIA.
Class No.

ORENSTEIN & KOPPEL,
Bush Lane House, Cannon Street,
LONDON, E.C.

Manufacturers of

LOCOMOTIVES

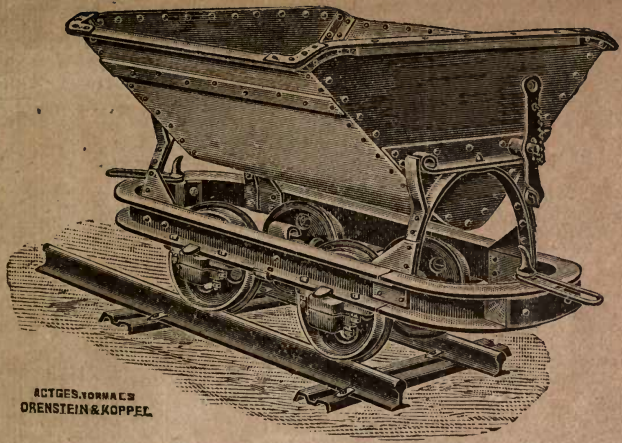
for Narrow and Standard Gauges.

Large Stocks kept for prompt delivery.

One Locomotive turned out every day.

Catalogues and Estimates free on application.

Telegraphic Address: "CUNEATIC, LONDON."



ORENSTEIN & KOPPEL,

Bush Lane House, Cannon Street,

LONDON, E.C.

Manufacturers of

PORTABLE RAILWAY PLANT,

POINTS AND CROSSINGS, TURNTABLES.

TIPPING CARS

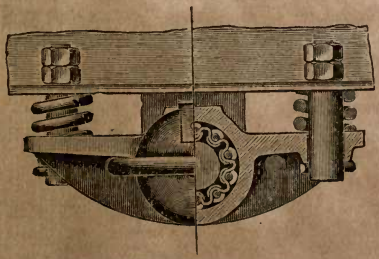
of every description.

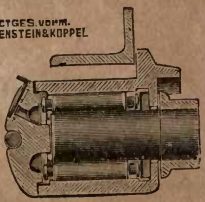
IMPROVED ROLLER BEARINGS,

SAVING 50 PER CENT. HAULAGE POWER.

Catalogues and Estimates free on Application.

Telegraphic Address: "CUNEATIC, LONDON."





ALBION CLAY CO., LIMITED.

WORKS: Woodville, Burton-on-Trent. | **LONDON OFFICE:** 18 New Bridge Street, E.C.

PURE STONEWARE Quotations given To any Ry. Station, or f.o.b.

TRADE GRANITIC STONEWARE MARK

DRAIN PIPES, &c. for all sizes, by Road. to any Port in England.

SYKES' PATENT STONEWARE STREET GULLY,

ALL SIZES.

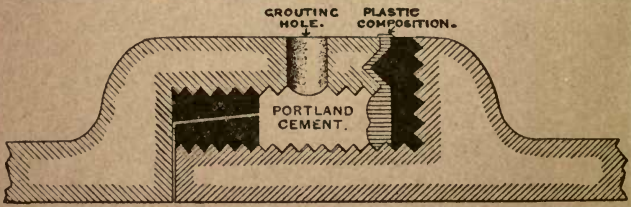
DEEP SEAL.
DEEP CATCHPIT.
EASY ACCESS.
OUTLET WELL BELOW CROWN OF ROAD.
Made also in Iron.

Awarded Medal of The Sanitary Institute, 1899.

LONGITUDINAL SECTION THROUGH C.D. SECTION THROUGH A B

PATENT PARAGON JOINT PIPE.

True Invert. Spigot cannot drop. Quickly laid. Moderate cost.



SYKES' NEW PATENT JOINT PIPE.

New Illustrated Catalogues and Price List Post Free.

THE

SEWERAGE ENGINEER'S NOTE-BOOK,

BEING

STANDARD NOTES ON SEWER FORMULÆ AND SEWERAGE CALCULATIONS.

BY

ALBERT WOLLHEIM, ASSOC.M.INST.C.E.

Reprinted from

"THE SURVEYOR AND MUNICIPAL AND COUNTY ENGINEER."

With numerous additional Tables and twenty-seven Diagrams.

SECOND (REVISED) EDITION.

ALL RIGHTS RESERVED.

REESE LIBRARY OF THE UNIVERSITY OF CALIFORNIA

London:

ST. BRIDE'S PRESS, LIMITED,

24 BRIDE LANE AND 13 NEW STREET HILL,

FLEET STREET, E.C.

1899

TD
W8
651

London:
St. Bride's Press, Limited,
printers and publishers,
24 Bride Lane and 13 New Street Hill,
Fleet Street, E.C.

PREFACE TO FIRST EDITION.

Evolved from notes and data originally collected and compiled by the author for his own use, and printed last year in serial form in THE SURVEYOR AND MUNICIPAL AND COUNTY ENGINEER, this little volume is now issued as a *vade mecum* for the sewerage engineer, the assistant and the student. Though more particularly designed to be kept on the office desk, its size will admit of its being carried in the pocket when giving evidence before Committees, as well as at Local Inquiries into Applications for Loans for Sewerage Works, where prompt answers always add greatly to the value of the evidence.

It is hoped that readers will come forward freely with additional tables, memoranda, diagrams and suggestions likely to improve the book. Such communications, addressed to the author (care of the publishers), will be appreciated and acknowledged in due course.

If "The Sewerage Engineer's Note-Book" in any way proves useful to that section of the profession for which it is intended, its *raison d'être* will be justified and the author's object will have been attained.

ALBERT WOLLHEIM.

LEADENHALL HOUSE,
LONDON, E.C.
March, 1896.

95994

PREFACE TO SECOND EDITION.

Owing to the large demand for copies of "The Sewerage Engineer's Note-Book," not only on the part of English engineers, but also from the profession in the Colonies and the United States, the author has acceded with pleasure to the publishers' request to revise the first edition, and trusts that the second edition will be received with as much favour its predecessor.

ALBERT WOLLHEIM.

December, 1899.

CONTENTS.

GENERAL FORMULÆ.

PART I.

PAGE

GENERAL FORMULÆ... 9

PART II.

STANDARD SECTION OF SEWERS 33

PART III.

SEWER DISCHARGE FORMULÆ 59

PART VI.

DIAGRAMS OF SEWER DISCHARGE AND VELOCITY ... 81

PART V.

THE RELATION BETWEEN RAINFALL AND SEWER DISCHARGE 103

APPENDIX.

APPENDIX 115

TABLE V.

PIPE SEWERS.—A (Sectional Area), R (Hydraulic Mean Depth), $\sqrt{R}$, and Multipliers for Velocity and Discharge 119

TABLE VI.

CIRCULAR SEWERS.—A (Sectional Area), R (Hydraulic Mean Depth), $\sqrt{R}$, and Multipliers for Velocity and Discharge 120

TABLE VII.

STANDARD EGG-SHAPE SEWERS.—A, R and $\sqrt{R}$ ... 123

TABLE VIII.

NEW EGG-SHAPE SEWERS.—A, R and $\sqrt{R}$ 125

TABLE IX.

STANDARD EGG-SHAPE SEWERS.—Multipliers for Velocity and Discharge 127

TABLE X.

PAGE

NEW EGG-SHAPED SEWERS.—Multipliers for Velocity and Discharge 130

TABLE XI.

$\sqrt{s}$ ($\sqrt{\text{Sine of Angle of Inclination}}$) for inclination up to 1 in 2000 133

TABLE XII.

QUANTITY OF BRICKWORK FOR CIRCULAR SEWERS ... 150

TABLE XIII.

QUANTITY OF BRICKWORK FOR EGG-SHAPE SEWERS ... 153

TABLE XIV.

EXCAVATION IN TRENCHES.—Cubic Yards per Lineal Yard of Trenches 154

TABLE XV.

SEWAGE FLOW.—Gallons per Minute 169

TABLE XVI.

SEWAGE FLOW.—Cubic Feet per Second... 170

TABLE XVII.

RAINFALL ON DRAINAGE AREAS.—Total Volume, Cubic Feet 171

TABLE XVIII.

RAINWATER.—Cubic feet per Second Rainflow, corresponding to Rate of Rainfall per Hour 172

TABLE XIX.

KUTTER'S CO-EFFICIENT "C" FOR DIFFERENT VALUES OF $\sqrt{R}$ AND n 173

USEFUL MEMORANDA 175

Part 1.

GENERAL FORMULÆ.

REESE LIBRARY OF THE UNIVERSITY OF CALIFORNIA

Part 1.

GENERAL FORMULÆ.

A = Sectional Area. P = Wetted Perimeter.
H.M.D. = Hydraulic Mean Depth.

$$\text{H.M.D.} = \frac{A}{P}$$

CIRCULAR SEWERS.

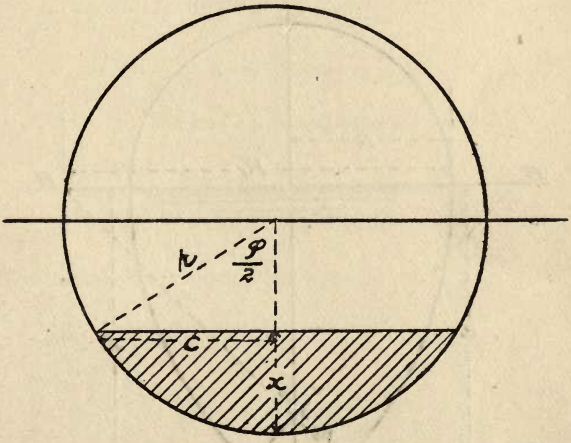


FIG. 1.

$$\text{A (full)} = d^2 \times \frac{\pi}{4} \qquad \text{P (full)} — d \times \pi$$

$$\text{A of segment} = \frac{4x}{3}\sqrt{(0{\cdot}626x)^2 + C^2}$$

(semi-chord C may be found by right-angled trigonometry)

$$\text{or A of segment} = \left(\frac{\phi}{180}\,\pi - \sin\phi\right)\frac{r^2}{2}$$

Perimeter of segment = number of degress × ·017453 rad.

EGG-SHAPED SEWERS.

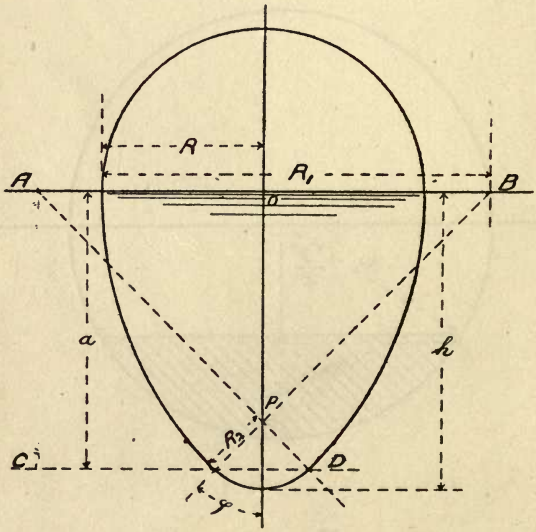


FIG 2

Let R = rad. of crown
R_1 = ,, sides = $m \times R$
R_2 = ,, invert = $n \times R$

then the following equations are correct for *all* values of R, R_1, R_2, ϕ, h and a, and for *all* shapes of four-centred egg-shaped sewers.

In the equations the values of $\sin \phi$ and $\cos \phi$ have to be determined. They can be calculated as follows: Since angles OPA and OPB are $= \phi$, we may calculate from the triangles thus :—

$$\sin \phi = \frac{R_1 - R}{R_1 - R_2} = \frac{m-1}{m-n}$$

$$a = m \times R \times \cos \phi$$

$$h = b\,[n + (m-n) \times \cos \phi$$

then

Case 1.—Sewer filled to line A B.

Total area below springing line A B =

$$R^2 \left[m^2 \times \frac{\pi}{2} - \left(m^2 - n^2\right)\left(\phi - \frac{\sin 2\phi}{2}\right) - 2m\left(m-1\right) \times \cos \phi \right] = \underline{\underline{c \times R^2}}$$

Perimeter below springing line A B =

$$2 \times R \times \left[n \times \phi + m\left(\frac{\phi}{2} - \phi\right) \right] = \underline{\underline{c_1 \times R}}$$

Case 2.—Sewers filled above line A B.

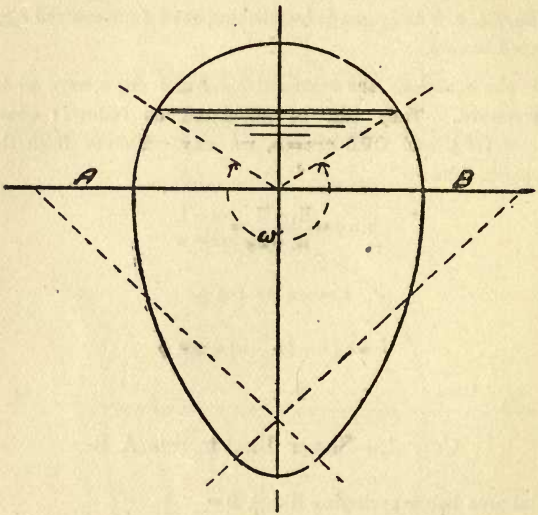


FIG. 3.

$$\text{Area} = \frac{R^2}{2} \times \left(2c + w - \pi - \sin w \right)$$

$$\text{Perimeter} = R(c_1 + w - \pi)$$

Case 3.—Sewer filled below A B.

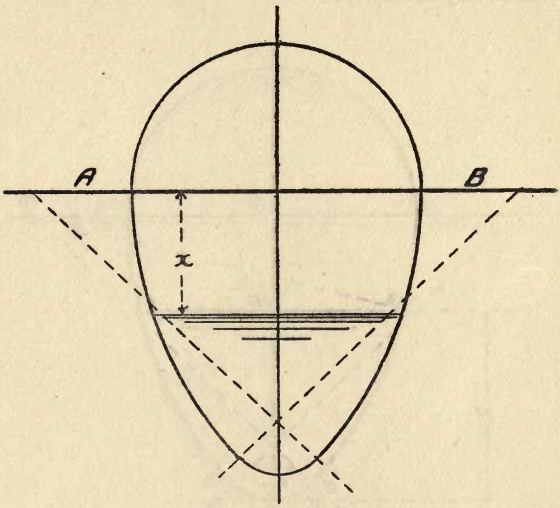


FIG. 4.

$$\text{Area} = R^2 \times \left[c - m^2 \times \text{arc}\left(\sin \frac{x}{m \times R} \right) \right] + x \left[2R \times (m-1) - \sqrt{m^2R^2 - x^2} \right]$$

$$\text{or } + R \times x \left[2(m-1) - m \sqrt{1 - \left(\frac{x}{m \times R} \right)^2} \right]$$

$$\text{Perimeter} = R \left[c_1 - 2m \times \text{arc}\left(\sin \frac{x}{m \times R} \right) \right]$$

or the area *abcd* (see Fig. 5) can be deducted from area two-thirds full. In the case of the ordinary egg-shape, with conjugate diameter = 1·5 transverse diameter, the following method may be employed :—

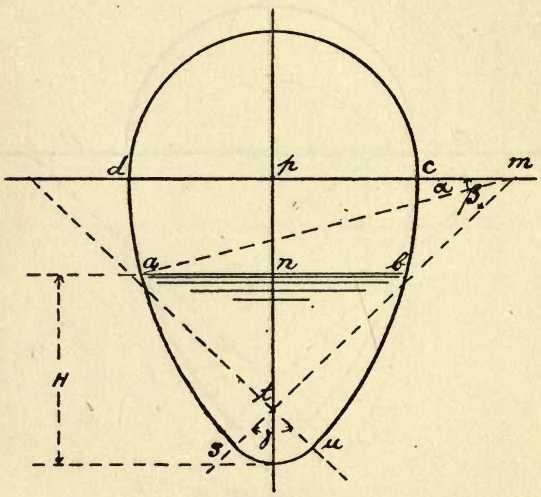


FIG. 5.

r = radius of crown

Find area $abcd = 3r^2\left(\frac{\pi a}{60^\circ} + \frac{3}{2}\sin 2a - 4 \sin a\right)$ and subtract this from area two-thirds full. This will be the area of the lower part, the height H, of which above invert is

$$H = 2r - pn = r(2 - 3 \sin a)$$

and the wetted perimeter of which =

$$\text{perim. two-thirds full} - \frac{2 \times a \times 3r\pi}{180}$$

Case 4.—Sewer filled to crown.

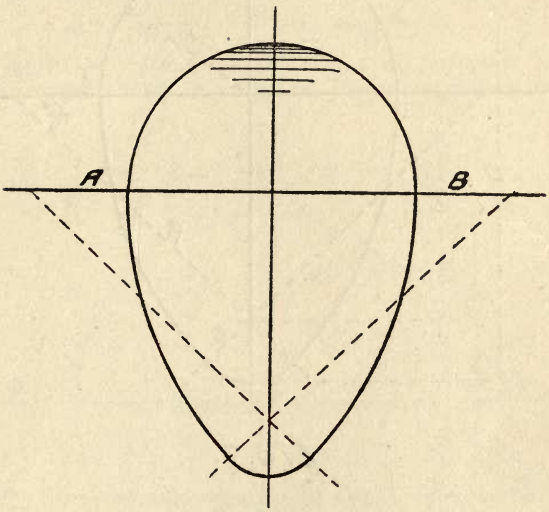


FIG. 6.

$$\text{Area} = \left(c + \frac{\pi}{2} \right) \times R^2$$

$$\text{Perimeter} = (c_1 + \pi) \times R$$

or, when it is required to find at the outset the area and perimeter of an egg sewer filled to crown, the following formulæ are useful :—

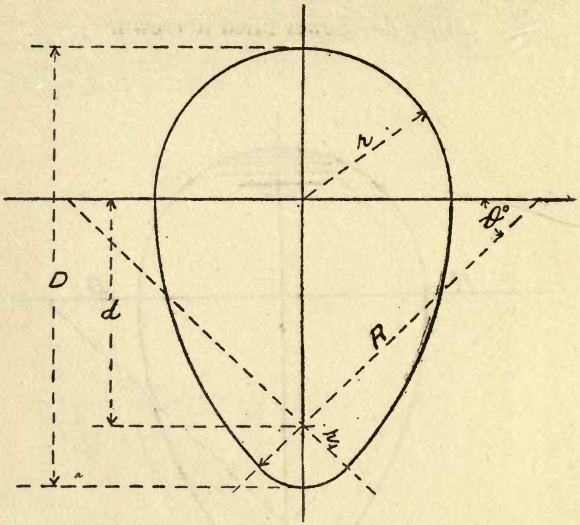


FIG. 7.

Let A = area.
R = radius of sides.
r = „ crown.
r_1 = „ invert.
P = perimeter.
D = total depth.
d = distance between centres of large and small circles, equal to $D-(r+r_1)$

Then we have

$$A=\frac{\pi}{180}\left[\theta^{\circ}(R^2-r_1^2)+90\,(r^2+r_1^2\right]-d\ (R-r)$$

$$P=\frac{\pi}{90}\left[\theta\,(R-r_1)+90\,(r+r_1)\right]$$

$$R=\tfrac{1}{2}\left(\frac{d^2}{(r-r_1)}+r+r_1\right)$$

The angle θ° subtended by the arc forming sides may be obtained from its sine or tangent, for

$$\sin\theta=\frac{d}{(R-r_1)} \qquad \tan\theta=\frac{d}{(R-r)}$$

EXAMPLES.—Required the area and perimeter of the sewer shown in Fig. 7A, having a radius of

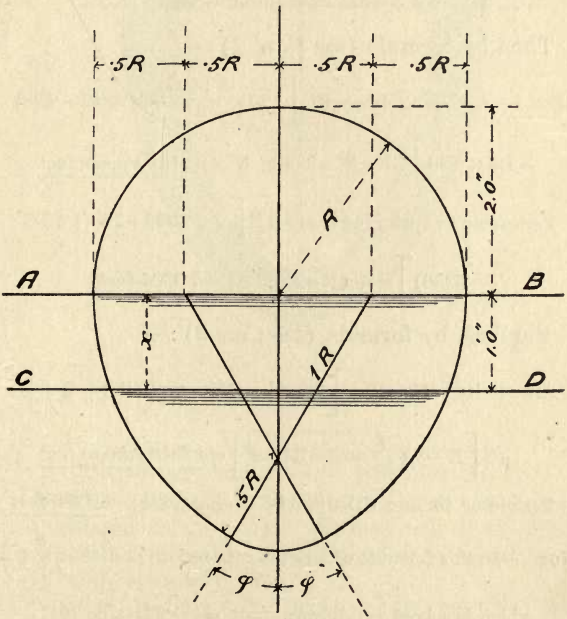


FIG. 7A.

crown=2 ft., the water level coinciding with springing line, also if flowing 1 ft. below spring line.

Here R (crown) $= 2$

R_1 (sides) $= m \times R = 1{\cdot}5 \times R = 3$

R^2 (invert) $= n \times R = {\cdot}5 \times R = 1$

Therefore $m = 1{\cdot}5$

$n = {\cdot}5$

$x = 1$

$$\sin \phi = \frac{m-1}{m-n} = \frac{{\cdot}5}{1{\cdot}0} = {\cdot}5 = \sin 30^\circ$$

$$\cos \phi = \cos 30^\circ = \sin 60^\circ = {\cdot}866$$

Then by formula (see *Case 1*) :—

$$\text{Area to springing line} = R^2 \left[1{\cdot}5^2 \times \frac{3{\cdot}1416}{2} - 2({\cdot}5236 - {\cdot}433) - 1{\cdot}5 \times {\cdot}866 \right] = c \times R^2 = 2{\cdot}0541\ R^2 = \underline{8{\cdot}2164 \text{ square feet}}$$

$$\text{Perimeter to springing line} = 2R \left[{\cdot}5 \times {\cdot}5236 + 1{\cdot}5\ (1{\cdot}5708 - {\cdot}5236) \right] = c_1 \times R = 3{\cdot}6652\ R = \underline{7{\cdot}3304 \text{ feet}}$$

Further, by formula (see *Case 3*) :—

$$\text{Area to line CD} = R^2 \times \left[2{\cdot}0541 - 2{\cdot}25 \times \text{arc}\left(\sin \frac{x}{1{\cdot}5\ R} \right) \right] + x \left[R - \sqrt{2{\cdot}25 = R^2 - x^2} \right] = \underline{4{\cdot}3216 \text{ square feet}}$$

$$\text{Perimeter to line CD} = R[3{\cdot}6652 - 3 \times {\cdot}3404] = \underline{5{\cdot}2886 \text{ feet}}$$

NOTE.—In the formula occurs the expression : $\text{arc}\left(\sin \frac{x}{1{\cdot}5\ R} \right)$

which is solved as follows : $\frac{x}{1{\cdot}5\ R} = \frac{1}{3} = {\cdot}33 = \text{sine } 19\frac{1}{2}^\circ$

Length of arc = number of degrees $\times$ ·017453

Therefore $19{\cdot}5 \times {\cdot}017453 = {\cdot}3404$

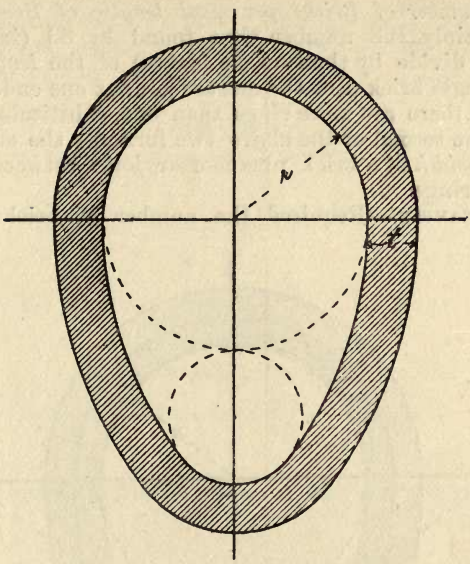


FIG. 7.

Area of brickwork = (inner perimeter + πt) t
External perimeter = inner perimeter + $2\pi t$

Number of Bricks.—As in sewer work the bricks are radiated to the proper curves, with their faces parallel and normal to the perimeter, we must treat each ring separately, thus :—

Number of Bricks per Ring.—For the first ring divide the inner perimeter P by the *thickness* of a course of brickwork increased by that of the mortar joint at the inner edge, which gives the number of bricks to go round.

Number of Bricks per yard length of Sewer.— Multiply the number thus found by 36 (inches) and divide by the sum (in inches) of the *length* of a single brick plus the mortar joint at one end.

If there are more rings than one, substitute for t in the second of the above two formulæ the sum of the *width* of a brick plus mortar joint between the two rings.

EXAMPLE.—Required the number of bricks per

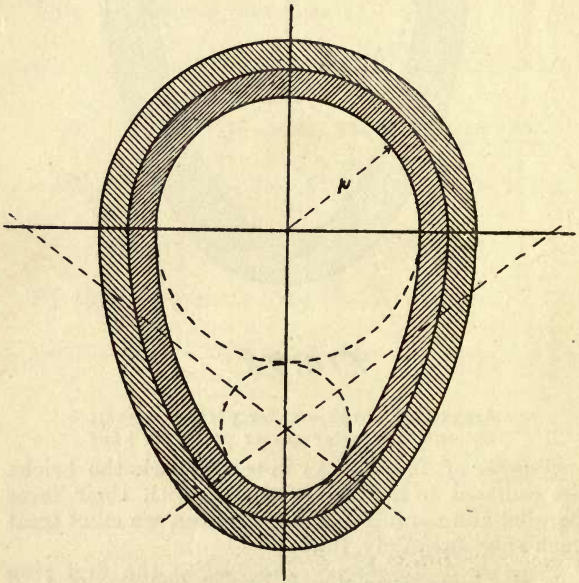


FIG. 7.

yard length of the sewer shown in the accompany-

ing figure. Size of bricks $8\frac{3}{4} \times 4\frac{1}{4} \times 2\frac{3}{4}$ in., mortar joints $\frac{1}{4}$ in. thick. r=rad. of crown in feet. Inner perimeter$=x \times r$ feet.

First Course—

$$\text{Perimeter} = 7{\cdot}93 \times r$$

$$\text{To go round, number} = \frac{7{\cdot}93 \times r \times 12}{3} = 32 \times r$$

$$\text{Per yard length, number} = \frac{32 \times r \times 36}{9} = 128 \times r$$

Second Course—

$$\text{Perimeter} = 7{\cdot}93 \times r + 2\pi \times \frac{4{\cdot}75}{12} = 7{\cdot}93 \times r + 2{\cdot}49$$

$$\text{To go round, number} = (7{\cdot}93 \times r + 2{\cdot}49)\frac{12}{2} = 32 \times r + 9{\cdot}96$$

$$\text{Per yard length, number} = (32 \times r + 9{\cdot}96)\frac{36}{9} = 128 \times r + 39{\cdot}8$$

By means of the above formulæ, if the size of bricks and thickness of mortar joints are given, tables of brickwork can be readily calculated for all the various sizes by simply substituting the values of r.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Part 2.

STANDARD SECTIONS OF SEWERS.

Part 2.

STANDARD SECTIONS OF SEWERS.

CIRCULAR SECTION.

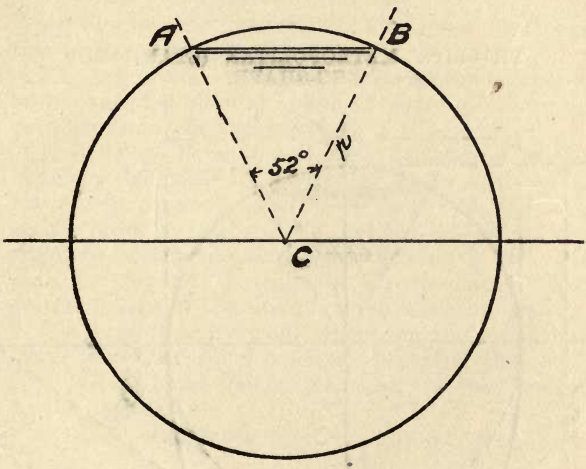


FIG. 8.

Area.	Perim.	H.M.D.	Depth of Flow.
$\cdot 7854d^2$	$3\cdot 1416d$	$\cdot 25d$	Full
$\cdot 632d^2$	$2\cdot 095d$	$\cdot 296d$	$\frac{3}{4}$,,
$\cdot 556d^2$	$1\cdot 911d$	$\cdot 292d$	$\frac{2}{3}$,,
$\cdot 395d^2$	$1\cdot 571d$	$\cdot 25d$	$\frac{1}{2}$,,
$\cdot 229d^2$	$1\cdot 231d$	$\cdot 186d$	$\frac{1}{3}$,,
$\cdot 154d^2$	$1\cdot 047d$	$\cdot 147d$	$\frac{1}{4}$,,

By Eytelwein's formula the maximum discharge of a circular sewer *not under pressure* occurs when the angle

$$ACB = 52°$$

—*i.e.*, when the depth of flow is

$$r(1+\cos 25°54') = 1{\cdot}899r = {\cdot}95d$$

By Kutter's formula the maximum discharge takes place at $\cdot 93d$—*i.e.*, when angle

$$ACB = 60°$$

PHILLIPS' METROPOLITAN (STANDARD) EGG-SHAPE.

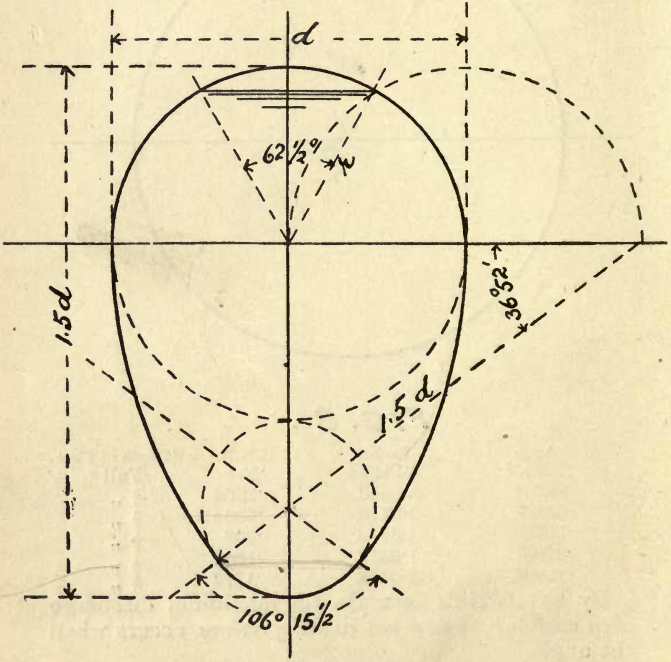


FIG. 9.

Area.	Perim.	H.M.D.	Depth of Flow.
$4{\cdot}594r^2$	$7{\cdot}930r$	$\cdot579r$	Full
$3{\cdot}518r^2$	$6{\cdot}291r$	$\cdot665r$	$\frac{3}{4}$,,
$3{\cdot}023r^2$	$4{\cdot}788r$	$\cdot631r$	$\frac{2}{3}$,,
$2{\cdot}037r^2$	$3{\cdot}783r$	$\cdot538r$	$\frac{1}{2}$,,
$1{\cdot}136r^2$	$2{\cdot}750r$	$\cdot413r$	$\frac{1}{3}$,,
$\cdot745r^2$	$2{\cdot}211r$	$\cdot337r$	$\frac{1}{4}$,,

By Eytelwein's formula the maximum discharge takes place when $\phi = 62\frac{1}{2}°$

The transverse diameter of this sewer compared with that of a circular sewer of equal discharging capacity is as ·8388 to 1·00.

This sewer flowing full will deliver twice the quantity delivered by a circular sewer with equal transverse diameter flowing $\frac{1}{2}$ full. If the egg sewer flows $\frac{1}{2}$ full it will deliver $1\frac{1}{2}$ times the quantity of the circular sewer flowing $\frac{1}{2}$ full. If both be flowing $\frac{2}{3}$ full, the circular sewer will deliver 5-7ths of the quantity delivered by the egg.

The relative proportions of the egg and a circular sewer to deliver equal volumes, provided they both flow full and the fall is identical, are represented by the equation :—

Diam. of circle : radius of egg :: 0·300 : 0·116;

$$\text{or diam. of circle} = \text{rad. of egg} \times \frac{0{\cdot}300}{0{\cdot}116} = \text{rad. of egg} \times 2{\cdot}59;$$

$$\text{or rad. of egg} = \text{diam. of circle} \times \frac{0{\cdot}116}{0{\cdot}300} = \text{diam. of circle} \times 0{\cdot}39$$

To ascertain the horizontal diameter by which to construct a standard egg-sewer equal in discharging capacity to a circular sewer of any diameter: Deduct the ninth part from the diameter of the circle, the remainder is the horizontal diameter of the equivalent egg.

The H.M.D. of a standard egg sewer, or any part of same, may be found by simply multiplying the H.M.D. of a sewer, the radius of whose crown is

unity, by the radius of the crown of an egg sewer of the same relative proportions, the H.M.D. of which it is required to find.

INVERTED STANDARD EGG-SHAPE.

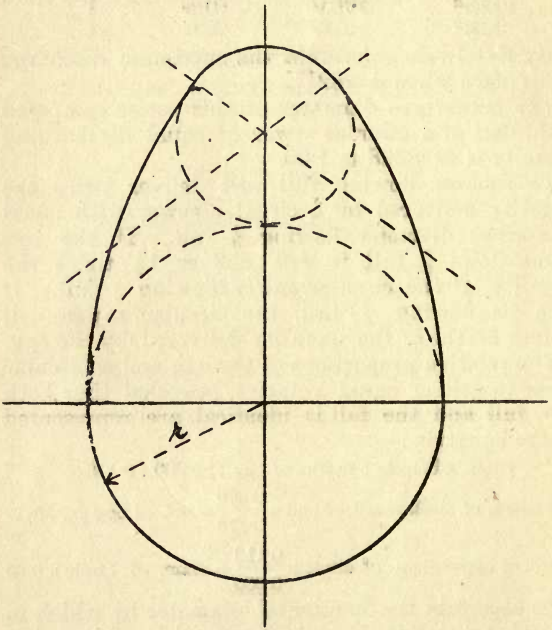


FIG. 10.

Area.	Perim.	H.M.D.	Depth of Flow.
$4{\cdot}594r^2$	$7{\cdot}930r$	$\cdot579r$	Full
$3{\cdot}849r^2$	$5{\cdot}719r$	$\cdot673r$	$\frac{3}{4}$,,
$3{\cdot}458r^2$	$5{\cdot}181r$	$\cdot667r$	$\frac{2}{3}$,,
$2{\cdot}557r^2$	$4{\cdot}147r$	$\cdot616r$	$\frac{1}{2}$,,
$1{\cdot}571r^2$	$3{\cdot}142r$	$\cdot500r$	$\frac{1}{3}$,,
$1{\cdot}076r^2$	$2{\cdot}639r$	$\cdot408r$	$\frac{1}{4}$,,

NEW EGG SHAPE.

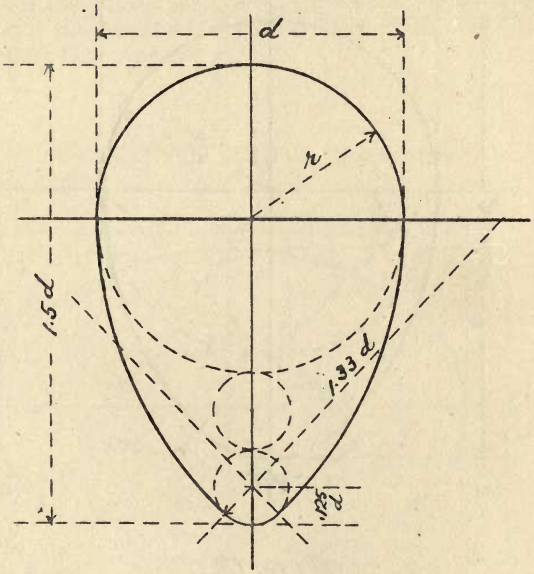


FIG. 11.

Area.	Perim.	H.M.D.	Depth of Flow
$4{\cdot}460r^2$	$7{\cdot}852r$	$\cdot569r$	Full
			$\frac{3}{4}$,,
$2{\cdot}889r^2$	$4{\cdot}699r$	$\cdot615r$	$\frac{2}{3}$,,
			$\frac{1}{2}$,,
$1{\cdot}017r^2$	$2{\cdot}649r$	$\cdot384r$	$\frac{1}{3}$,,
			$\frac{1}{4}$,,

HAWKSLEY'S EGG SHAPE.

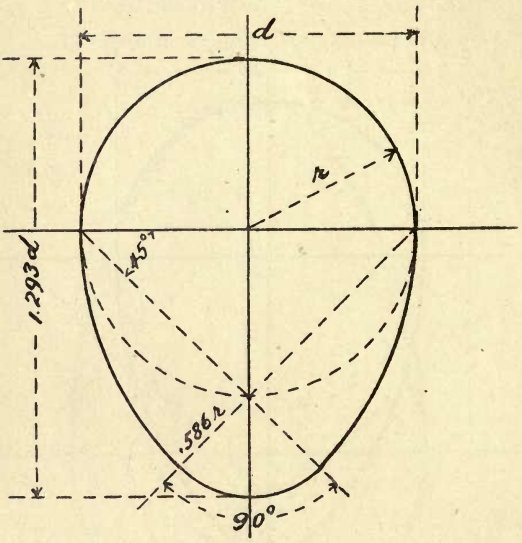


FIG. 12.

Area.	Perim.	H.M.D.	Depth of Flow.
$3{\cdot}982r^2$	$7{\cdot}203r$	$\cdot553r$	Full
$2{\cdot}686r^2$	$4{\cdot}337r$	$\cdot620r$	$\frac{2}{3}$ „
$1{\cdot}028r^2$	$2{\cdot}596r$	$\cdot396r$	$\frac{1}{3}$ „

As compared with a circular sewer of same diameter, the area is as 1·27 to 1·00. Consequently, when the areas are equal the diameters will be as 8 to 9 nearly.

Therefore, (1) to find diameter of circular sewer of equal discharging capacity add the eighth part of the transverse diameter; (2) conversely, given a circular sewer to find diameter of equivalent egg, deduct the ninth part of the diameter of circular sewer; the remainder will be the transverse diameter of the egg sewer.

FOUR-CENTRE ELLIPSE (HORIZONTAL).

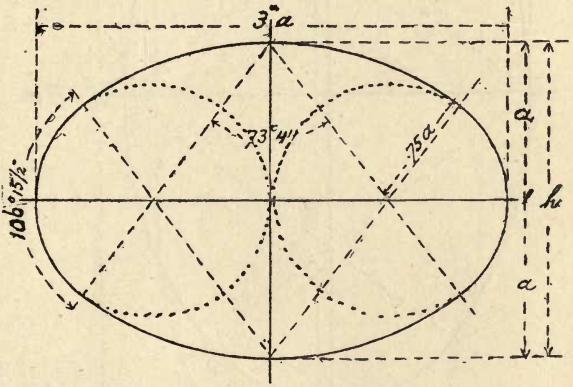


FIG. 13.

Area.	Perim.	H.M.D.	Depth of Flow.
$4{\cdot}691a^2$	$7{\cdot}930a$	$\cdot 592a$	Full
$3{\cdot}785a^2$	$5{\cdot}060a$	$\cdot 748a$	$\frac{3}{4}$,,
$3{\cdot}328a^2$	$4{\cdot}655a$	$\cdot 715a$	$\frac{2}{3}$,,
$2{\cdot}345a^2$	$2{\cdot}965a$	$\cdot 592a$	$\frac{1}{2}$,,
$1{\cdot}362a^2$	$3{\cdot}275a$	$\cdot 416a$	$\frac{1}{3}$,,
$\cdot 905a^2$	$2{\cdot}870a$	$\cdot 315a$	$\frac{1}{4}$,,

FOUR-CENTRE ELLIPSE (UPRIGHT).

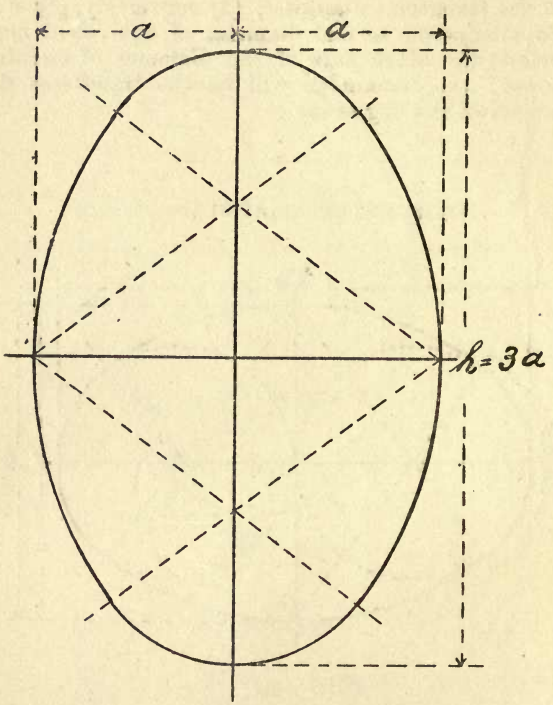


FIG. 14.

Area.	Perim.	H.M.D.	Depth of Flow.
$4{\cdot}691a^2$	$7{\cdot}930a$	$\cdot592a$	Full
$3{\cdot}773a^2$	$5{\cdot}503a$	$\cdot686a$	$\frac{3}{4}$,,
$3{\cdot}324a^2$	$4{\cdot}997a$	$\cdot668a$	$\frac{2}{3}$,,
$2{\cdot}345a^2$	$3{\cdot}965a$	$\cdot592a$	$\frac{1}{2}$,,
$1{\cdot}366a^2$	$2{\cdot}953a$	$\cdot462a$	$\frac{1}{3}$,,
$\cdot917a^2$	$2{\cdot}427a$	$\cdot378a$	$\frac{1}{4}$,,

The diameter of this ellipse, compared with a circular sewer of equal discharging capacity, is as ·8272 to 1·00.

VARIOUS OTHER SECTIONS.

ELONGATED STANDARD EGG SHAPE (FOR INCREASED HEADWAY).

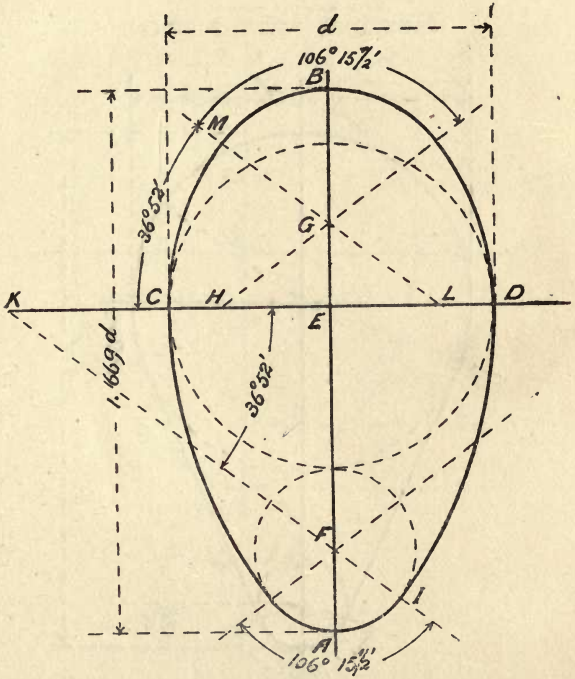


FIG. 14A.

Area (full) = $1{\cdot}358d^2$ Perimeter = $4{\cdot}243d$ H.M.D. = $\cdot 321d$

AB = $1\frac{2}{3}$ CD
AE = CD
AF = $\frac{1}{4}$ CD
GE = $\frac{1}{4}$ CD
CH = $\frac{1}{6}$ CD
LM = $\cdot 833d$
GH = $\cdot 414d$
IK = parallel to LM

Area CBDEC = $\cdot 602d^2$ Perimeter CBD = $1{\cdot}849d$

JACKSON'S PEG-TOP SHAPE.

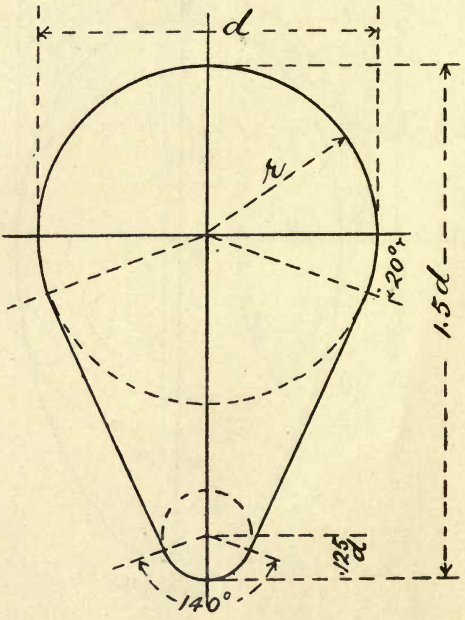


FIG. 15.

Area.	Perim.	H.M.D.	Depth of Flow.
$4{\cdot}154r^2$	$7{\cdot}756r$	$\cdot 536r$	Full
$2{\cdot}583r^2$	$4{\cdot}614r$	$\cdot 560r$	$\frac{2}{3}$ „
$\cdot 969r^2$	$2{\cdot}541r$	$\cdot 381r$	$\frac{1}{3}$ „

OVOID SHAPE, (WITH FOUR INTERNATIONAL CENTRES).

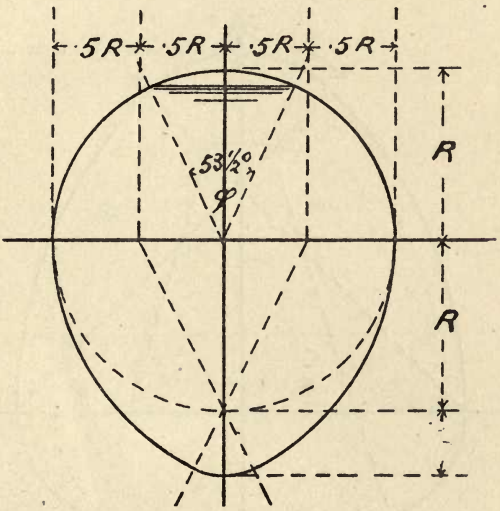


FIG. 16.

Rad. of Invert = ·382 R.

Maximum discharge when $\phi = 53\frac{1}{2}°$

CATENARY SHAPE (Boston, U.S.A., Main Drainage).

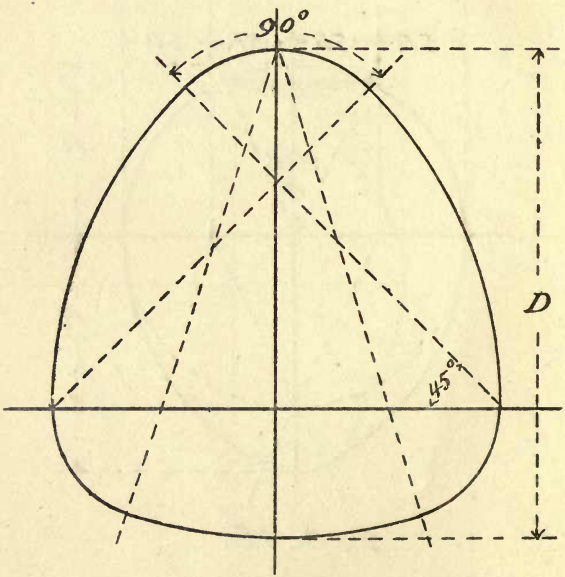


FIG. 17.

SEMI-CIRCULAR CROWN, SEGMENTAL INVERT

(Outfall Sewer).

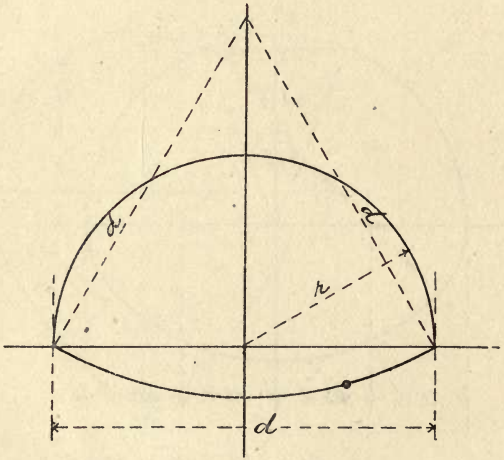


FIG. 18.

Area (full) $= 1{\cdot}912r^2$ Perim. $= 5{\cdot}236r$ H.M.D. $= {\cdot}365r$

REESE LIBRARY OF THE UNIVERSITY

SEMI-CIRCULAR CROWN, ELLIPTICAL INVERT

(Outfall Sewer).

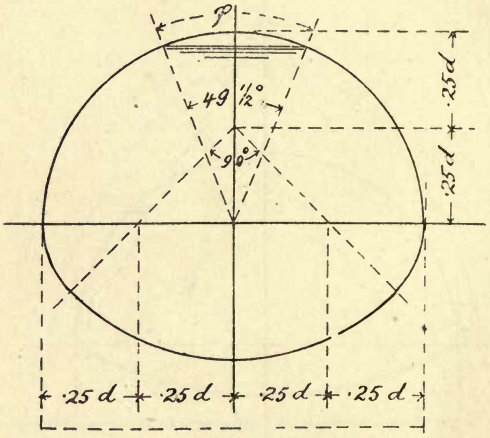


FIG. 19.

Area (full) = $\cdot 7267 d^2$ Perim. = $2 \cdot 9106 d$ H.M.D. = $\cdot 249 d$

Maximum discharge when $\phi = 49\frac{1}{2}°$

CONTRACTED HYPERBOLIC SHAPE.

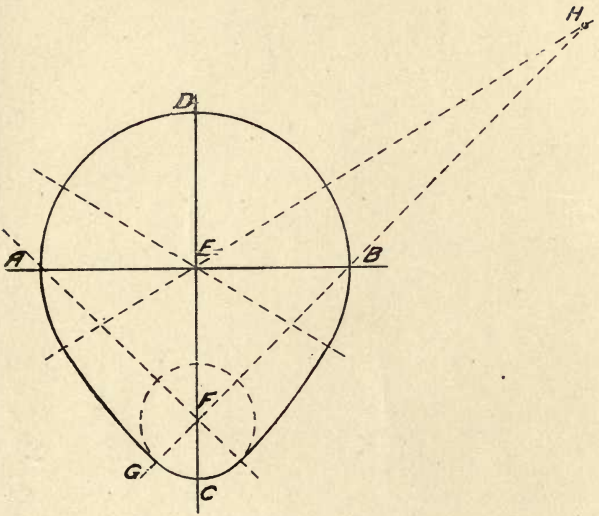


FIG. 20.

Construction Divide AB into 11 parts,

then EC	=	$7\frac{1}{2}$ „	= ·682 AB
CD	=	13 „	= 1·182 „
FC	=	2 „	= ·182 „
GH	=	$21\frac{2}{3}$ „	= 1·969 „

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Part 3.

SEWER DISCHARGE FORMULÆ.

Part 3.

SEWER DISCHARGE FORMULÆ.

It is astonishing that English sewerage engineers of the present day give so little attention to a subject of great importance—namely, the actual discharge of sewers of all sizes. Whilst in countries which may, as regards sewerage works, be said to be behind England (as, for instance, Germany and the United States of America) important experiments on sewer discharge have been and are being carried out, little or nothing appears to be done in this country to further investigate the subject. It seems hardly credible that, in the light of recent investigations, the great majority of English engineers should still base their calculations on tables of discharge derived from obsolete formulæ which have been proved to err as much as from 30 to 40 per cent. Moreover, the author has found that the number of those who are acquainted with what may be termed the inner history of sewer discharge formulæ is very limited ; therefore he believes that a brief analysis of some of the more important formulæ that have been proposed from time to time will prove of more than ordinary interest to a large circle of engineers engaged in or connected with sewerage works.

Chezy and Eytelwein's Formula.—About a century ago two eminent engineers, Chezy, a Frenchman, and Eytelwein, a German, found that the flow of water in channels could be expressed by the general formula :—

$$V = c\sqrt{R \times S}$$

where V = mean velocity of water, feet per second.

$$R = \text{hydraulic mean radius} = \frac{\text{area of cross section, sq. ft.}}{\text{wetted perimeter, lin. ft.}}$$

$$S = \text{slope} = \frac{\text{inclination of water surface.}}{\text{length of channel.}}$$

c = a coefficient determined by experiment.

This is the fundamental formula from which nearly all subsequent ones have been deduced. Chezy and Eytelwein found the value of c to be 93·4, assuming it to be constant for all variations of size and inclination; a fallacy that was only dispelled after a long time, when it was discovered that the coefficient was not a constant but a variable. Nevertheless, even in very recent times, numbers of engineers have conducted experimental gaugings on some particular sewer under their charge, and having arrived at a constant c which differed materially from the one fixed by the two experimenters above named, have simply substituted their own constant in the general formula, ignoring all the time the fact that the assumption of a constant value for c is a fallacy. If a hundred experimenters were to gauge a hundred different sized sewers, one each, they would find greatly different values, differing among each other probably as much as 40 per cent. in extreme cases. In this connection the author feels compelled to sound a note of warning on the subject of sewer discharge gaugings generally. Such gaugings, if undertaken with the object of establishing new values of the coefficient c, and if any reliance is to be placed on the results obtained, should only be undertaken by men well

versed in hydraulics, who are competent to take all the necessary precautions in connection with and avoid all those errors which are liable to destroy the value of the experiments. But, above all, it is absolutely necessary that the experiments be conducted or superintended *persona ipsissima*, and not relegated to subordinates. It seldom happens that in a system of town sewers the conditions are favourable for conducting experimental gaugings on a scientific basis without necessitating a considerable amount of preparation for that special purpose. One of the first conditions is that the length of sewer experimented upon should have a uniform slope and a free outfall. Further, there should be a tank at the outlet, so as to make the measurements of quantities positive. The employment of weir gauges is objectionable, for the reason that the discharge over such weirs has to be calculated by a formula, the correctness of which depends upon a certain coefficient of discharge, which varies enormously according to the form of weir employed and other circumstantial conditions. To determine the mean velocity by floats is also an unreliable mode of procedure. The mean velocity is easily and correctly deduced from the positive tank measurements. Then, again, while any one experiment lasts the depth of flow in the sewer should be perfectly steady. This is a condition difficult to satisfy in town sewers unless special means are provided for feeding the experimental sewer from some reservoir or large sewer at its head. One of the most favourite times chosen for experimental gaugings is during a storm, but it is in reality the worst time that could be selected, for the following reasons: As has been shown in a previous chapter, no sewer ever runs full bore *except when it is put*

under pressure, a condition to which ordinarily no sewer should ever be subjected where it can be avoided. But inasmuch as few systems of sewers can be designed large enough to carry away storm water without a certain amount of gorging taking place towards the lower portions of the system, and especially in the main outfall sewers, therefore the fact of the sewer running full bore, or nearly full bore, is *primâ-facie* evidence of its being under pressure; and to endeavour to determine with accuracy the head producing the pressure on the sewer is a problem the solution of which requires exceptional care. But granted we have a sewer which does not run under pressure during storms, then the probabilities are that the depth of flow will not be constant, but will be continually changing according to the progress of the storm; and to attempt to deduce a coefficient of discharge under such conditions would be entirely misleading.

Weisbach's Formula.—The next important formula proposed was that of Weisbach. It has since been simplified and modified by others, as have also the other formulæ; but for the purpose of our investigation it will be best to give all formulæ in their original constitution, as then their development one from the other can be better appreciated. The Weisbach formula is:—

$$V = \left[\sqrt{\frac{2g}{A\left(1+\frac{B}{v}\right)}}\right]\sqrt{R\times S} = c\sqrt{R\times S}$$

in which there appear new terms, namely:—

$2g$ = acceleration due to gravity.
A and B = empirical constants.

It will be seen that the coefficient c is expressed by the bracketed portion, and is not a constant, as in the previous formula, but varies with the velocity.

D'Arcy and Bazin's Formula.—Then came the two eminent French engineers, who, after extensive experiments, arrived at the conclusion that the hydraulic mean radius had a considerable influence on the value of the coefficient c. Moreover, they were the first to discover the important retarding effect produced on the quantity discharged by the friction of the material of which a channel is composed. The formula is:—

$$V = \left[\sqrt{\frac{2g}{a\left(1+\frac{\beta}{R}\right)}}\right] \sqrt{R \times S} = c \sqrt{R \times S}$$

where R = hydraulic mean radius.
a and β = variables changing with the degree of roughness of the channel.

but, although this formula looks very much like that of Weisbach, it will be seen that it really expresses totally different laws.

Kutter and Ganguillet's Formula.—The last-mentioned formula, which was the outcome of the experiments of the two French engineers, formed the basis of those researches and experiments undertaken by the two eminent Swiss engineers, Kutter and Ganguillet, which for their thoroughness and logical reasoning, combined with mathematical investigative skill, take high rank among practical investigations, not only in this, but also in other fields of engineering. It is, perhaps, not generally known that the experiments were chiefly conducted by Kutter himself, whilst the mathematical calculations were for the most part left in the hands of Ganguillet. The formula reads:—

$$V = \left[\frac{41{\cdot}6 + \frac{1{\cdot}811}{n} + \frac{{\cdot}00281}{S}}{1 + \left(41{\cdot}6 + \frac{{\cdot}00281}{S}\right)\frac{n}{\sqrt{R}}} \right] \sqrt{R \times S} = c\sqrt{R \times S}$$

where n = coefficient of roughness of the material of which the channel is composed.

Briefly stated, Kutter found that the coefficient of discharge c *varies*. 1, With the degree of roughness of the wetted perimeter, decreasing with the increase of roughness. 2, With the value of the hydraulic mean radius, increasing with its increase. 3, With the slope, decreasing with its increase in large streams and increasing with its increase in small channels. Further, c *increases*. 1, With the increase of R, and most rapidly when R is small. 2, With the decrease of the resistance to flow—*i.e.*, with the decrease of roughness of the perimeter; so that for constant values of R and S n is also greatest for the smoothest channel and smallest for the roughest channel. This influence of roughness upon c is also greatest for the smallest value of R. 3, With the decrease of S, if R is greater than $3\frac{1}{3}$ ft. (1 mètre), and also in small channels if the wetted perimeter is very rough in comparison with the area of cross-section. 4, With the increase of S, if R is greater than $3\frac{1}{3}$ ft., and if the wetted perimeter is smooth. Or the above laws may be summarised as follows: 1, c, or the velocity, and consequently the discharge, varies with every change in the value of R, S and n and if the slope and n remain the same, then c increases with the increase of R—*i.e.*, with the increase of the diameter. 2, c increases with the increase of slope for all diameters whose H.M.D. is less than $3\frac{1}{3}$ ft., and

with an H.M.D. greater than $3\frac{1}{3}$ ft. an increase of slope gives a diminution of c.

TABLE I.

Values of c.

12 ft. diameter.		20 ft. diameter.	
1 in 1,000	1 in 40	1 in 1,000	1 in 40
137·7	137·9	146·0	145·7

It will thus be seen that by Kutter's formula, when R=3 ft.—that is, less than $3\frac{1}{3}$ ft.—an increase in the slope from 1 in 1,000 to 1 in 40 makes a slight increase in the coefficient; but when R is 5 ft.—that is, more than $3\frac{1}{3}$ ft.—the same increase in the slope causes a slight decrease in the value of c.

The values of n for different materials, as found by Kutter, and subsequently corroborated by thousands of gaugings, chiefly by German and American engineers, are as follows:—

n=·010 for rendered surfaces in pure cement, glazed, coated or enamelled stoneware and iron pipes; glazed surfaces of every kind in perfect order.

n=·011 for rendered surfaces with two parts sand to one cement; for uncoated iron pipes, cement pipes, well jointed and in best order.

n=·013 for ashlar and well-laid brickwork; earthen and stoneware pipes, in good condition but not new, and generally the surfaces mentioned with n=·010 and ·011 when in bad condition.

n=·015 for rough brickwork, well-dressed stonework, iron and cement pipes, with imperfect joints and in very bad condition.

n=·017 for brickwork, ashlar and stoneware in bad condition.

• The effect of varying n can be seen from the following table :—

TABLE II.

(Robert Moore, M.AM.SOC.C.E.)

Giving values of c in Kutter's formula (when S=·001 constant).

	Values of n.					
R	·010	·011	·012	·013	·015	·017
·1	93·8	82·2	72·7	65·0	53·2	44·6
·2	113·1	100·0	89·1	80·2	66·3	56·2
·3	123·8	111·0	98·8	90·2	75·0	63·4
·4	132·5	118·0	106·0	96·2	80·4	68·8
·5	138·6	123·8	111·2	101·2	85·1	72·8
·6	143·3	128·3	115·7	105·3	88·8	76·4
·7	147·4	131·9	119·3	108·7	92·0	79·3
·8	150·8	135·1	122·3	111·6	94·6	81·9
·9	153·7	137·8	125·1	114·2	97·0	84·2
1·0	156·2	140·5	127·4	116·5	99·1	86·0
1·2	160·4	144·6	131·5	120·4	102·7	89·4
1·4	164·0	147·9	134·7	123·7	105·7	92·2
1·6	167·0	150·8	137·4	126·2	108·2	94·5
1·8	169·5	153 2	139·7	128·7	110·3	96·6
2·0	171·6	155·4	141·8	130·5	112·3	98·4
2·2	173·5	157·3	143·7	132 3	114·0	100·0
2·4	175·2	159·0	145·3	133·9	115·4	101·4
2·6	176·8	160·5	146·8	135·3	116·8	102·8
2·8	178·2	161·8	148·1	136·7	118·0	104·0
3·0	179·4	163·2	149·3	137·9	119·2	105·1
3·4	181·7	165·3	151·4	140·0	121·3	107·1
3·8	183·6	167·2	153·3	141·8	123·0	108·8
4·2	185·3	168·8	155·0	143·4	124·6	110·3
4·6	186·8	170·3	156·4	144·8	125·9	111·6
5·0	188·1	171·6	157·7	146·0	127·2	112·9

It will have been already noticed when examining Table I. that the variation of slope produces only a comparatively slight variation of the coefficient c. Now it has been found that if a slope of 1 in 1,000 be taken as a standard, then for slopes usually met with in ordinary sewer practice the differences will

average only about $\frac{1}{2}$ per cent. The subjoined table will make this clear.

TABLE III.

Showing the effect of S=variable and S=·001 constant:—

Diam.	Incline.	S=variable. Veloc. ft. per sec.	S=variable. Discharge c. ft. per s.	S=·001 constant. Velocity ft. per s.	S=·001 constant. Discharge c. ft. per s.
5	1 in 4,400	2·001	39·3	2·03	40·0
7	1 in 1,150	4·986	191·9	5·00	192·2

It is therefore evident that in the Kutter formula S may, for all practical purposes, be taken as 1 in 1,000=·001 constant. Substituting ·001 for S in the formula, it becomes

$$V = \left[\frac{41{\cdot}6 + \frac{1{\cdot}811}{n} + \frac{{\cdot}00281}{{\cdot}001}}{1 + \left(41{\cdot}6 + \frac{{\cdot}00281}{{\cdot}001}\right)\frac{n}{\sqrt{R}}} \right] \sqrt{R \times S}$$

and substituting the values of n we obtain

$$\text{when } n = {\cdot}010,\ V = \left[\frac{225{\cdot}6}{1 + 44{\cdot}41 \times \frac{{\cdot}010}{\sqrt{R}}} \right] \sqrt{R \times S}$$

$$= \left[\frac{225{\cdot}6}{1 + \frac{{\cdot}445}{\sqrt{R}}} \right] \sqrt{R \times S}$$

and so on for the other values of n.

Flynn's Simplified Kutter Formula.—Now, calling the numerator K, and substituting x for the fractional numerator over $\sqrt{R}$, we have the general formula

$$V = \left[\frac{K}{1 + \frac{x}{\sqrt{R}}} \right] \sqrt{R \times S}$$

and we can now compile the following table :—

TABLE IV.

When n =	K	x
·010	225·6	·445
·011	209·1	·489
·012	195·4	·534
·013	183·8	·578
·015	165·2	·667
·017	150·9	·756

The above abbreviation and simplification of the Kutter formula is due to the late P. J. Flynn, C.E., a well-known American hydraulic engineer, and it is known as "Flynn's Simplified Kutter Formula." Its beautiful simplicity must commend it to all sewerage engineers, and it is therefore not surprising to find all the more recent tables and diagrams of sewer discharge of American engineers based on this formula. The original Kutter formula has been almost exclusively used by German and American engineers during the last decade; and, as a rule, even English engineers acknowledge that it is the most scientifically correct one that has ever been devised, but, owing to its complexity, no doubt, other simple, but less reliable and less correct, formulæ have hitherto been preferred in England. However, with the adoption of Flynn's modifications. the "complexity" of Kutter's formula disappears. He who supplies a long-felt want deserves well of his fellow-men. This is very forcibly shown by the delight with which the extensive tables of sewer discharge recently published in THE SURVEYOR

were received by a large number of municipal and sanitary engineers. The author's aim is to draw attention to the labour-saving tables of calculated results due to the late Mr. Flynn, which render the application of Kutter's formula, and of other sewer formulæ, a matter of the greatest ease and pleasure. Looking again at the general formula

$$V = \left[\frac{K}{1 + \frac{x}{\sqrt{R}}} \right] \sqrt{R \times S}$$

and supposing we wish to apply it to the solution of a sewer discharge problem, it will be at once apparent that, although we can take the values of K and x from Table IV., we require tables of R, S, $\sqrt{R}$ and $\sqrt{S}$, but more particularly the two latter, in order to avoid tedious calculations. The fault of a great many of the tables printed in English standard text-books is that they are incomplete—*i.e.*, they do not proceed by units, but skip by tens and twenties, and the chances are the engineer in nine cases out of ten will find them useless.

From the general formula

$$V = c\sqrt{R \times S}$$

the following additional formulæ are deduced

For velocity

$$V = c\sqrt{R} \times \sqrt{S} \qquad (1)$$

$$c\sqrt{R} = \frac{V}{\sqrt{S}} \qquad (2)$$

$$\sqrt{S} = \frac{V}{\sqrt{R}} \qquad (3)$$

and further, as $Q = A \times V$, therefore

For discharge

$$Q = A \times c\sqrt{R} \times \sqrt{S} \qquad (4)$$

$$A \times c\sqrt{R} = \frac{Q}{\sqrt{S}} \qquad (5)$$

$$\sqrt{S} = \frac{Q}{A \times c\sqrt{R}} \qquad (6)$$

The above six formulæ are readily applied to the following six problems, frequently occuring in sewerage calculations:—

		Problem.
Formula.	Required.	Given.
(1)	Velocity.	Diameter and Inclination.
(2)	Diameter.	Velocity and Inclination.
(3)	Inclination.	Diameter and Velocity.
(4)	Discharge.	Diameter and Inclination.
(5)	Diameter.	Discharge and Inclination.
(6)	Inclination.	Diameter and Discharge.

In the appendix will be found tables of area (A), hydraulic mean depth (R), $\sqrt{R}$, sine of slope (S) and $\sqrt{S}$. The value of these, more especially the two latter, in expediting sewerage calculations will be apparant to anyone who has ever had such calculations to do.

Reverting once more to the fundamental formula

$$V = c\sqrt{R \times S}$$

this, at has been shown above, can be written

$$= c\sqrt{R} \times \sqrt{S}$$

and as we possess tables of C, $\sqrt{R}$ and $\sqrt{S}$, etc., the calculation resolves itself into one of simple multiplication.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Part 4.

DIAGRAMS OF SEWER DISCHARGE AND VELOCITY.

Part 4.

DIAGRAMS OF SEWER DISCHARGE AND VELOCITY.

The advantages of diagrams over tables of calculated results are threefold: 1, Diagrams possess the great advantage of presenting to the eye a clear conception of the relation of results derived from a variety of assumptions in any given solution; 2, Serious errors in their construction cannot remain unnoticed; 3, The same information is presented in but a small fraction of the space required for tables.

RELATIVE DISCHARGE AND VELOCITY AT DIFFERENT DEPTHS OF FLOW.

It has already been pointed out in Part II. (*see* Fig. 8) that, if calculated by the old formula, such as Eytelwein's, the maximum discharge of a circular sewer would take place when depth of flow = ·95 *d* and the angle ACB = 52°. But if the more correct formula of Kutter be employed, the maximum discharge would take place at ·93 *d*, corresponding to an angle of 60°. Now it seems strange to an observant mind that to this day unanimity is wanting as to the exact depth at which the maximum discharge does actually occur. It only goes to show how great is the difficulty of conducting sewer gaugings which may be termed exact in the

strictest sense of the word, and what a large field there still remains open to the experimenter. However, the author hopes that he has made it clear in the preceding parts that Kutter's is by far the most correct formula to employ.

The subjoined table will prove useful in comparing the relative proportional value of discharge and velocity if calculated by Eytelwein's and Kutter's formula respectively—*i.e.*, when C remains constant and when it varies. The values by Kutter's are averages for the different sizes of pipes, but the variation due to size of pipe is comparatively insignificant. The depth is given in terms of the diameter.

TABLE A.

Giving proportional values of velocity and discharge for *circular sewers* at different depths of flow.

(Values for *full* pipes are taken as unity.)

Depth.	Eytelwein (*c* constant). Velocity.	Discharge.	Kutter (*c* variable.) Velocity.	Discharge.
1·0 (full)	1·00	1·00	1·00	1·00
·90	1·09	·99	1·14	1·08
·80	1·10	·94	1·15	·95
·75 (¾ full)	1·09	·88	1·14	·92
·70	1·08	·82	1·12	·84
·60	1·05	·66	1·08	·68
·50 (½ full)	1·00	·50	1·00	·50
·40	·93	·35	·89	·33
·30	·83	·21	·75	·19
·25 (¼ full)	·76	·15	·66	·13
·20	·70	·10	·57	·08
·10	·50	·02	·34	·02

In the foregoing table the velocity and discharge *when flowing full* are taken as unity. But as recent formulæ and experiments seem to teach us that the maximum discharge and velocity occur when the sewer is flowing not quite full, some have advocated

that the points of maximum discharge and velocity should rather be taken as unity, as shown below.

TABLE B.

(Based on Kutter's formula.)

Giving proportional value of velocity and discharge for *circular sewers* at different depths of flow.

(*Maximum* velocity and discharge are taken as unity.)

Depth.	Velocity.	Discharge.
1·00 (full)	·86	·916
·93	·96	1·000
·90	·98	·992
·81	1·00	·924
·80	·99	·912
·75 (¾ full)	·99	·850
·70	·98	·776
·60	·93	·620
·50 (½ full)	·86	·450
·40	·76	·302
·30	·64	·168
·25 (¼ full)	·57	·118
·20	·48	·072
·10	·28	·016

But considering that no sewer ever can run quite full by gravitation alone, and that it must be put under pressure to do so, it is more probable that further investigation and experiments will reveal the fact that a sewer running under a head just sufficient to fill it to the crown discharges at least the same quantity as when running at its maximum capacity by gravitation only.

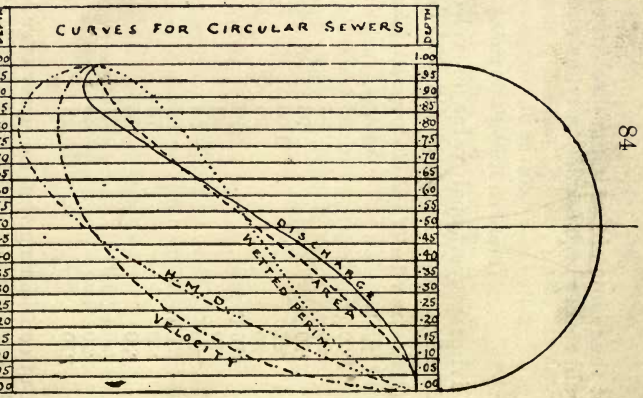
Fig. 21 gives in a condensed form the substance of a paper contributed to the "Proceedings" of the Institution of Civil Engineers, in 1889, by Mr. R. M. Gloyne, A.M.I.C.E. The table and curves give the proportional values of area, perimeter, hydraulic mean depth and discharge at various depths of

Proportionate Values of Area, Wetted Perimeter, Hydraulic Mean Depth, Velocity and Discharge, for Circular and Standard Egg-shaped Sewers, at different Depths of Flow.

This diagram is computed by Eytelwein's formula.

(See also Tables 9 and 10, *ante*.)

AREA	WETTED PERIM	H.M.D.	VELOCITY	DISCH.	DEPTH
1.00	1.00	1.00	1.00	1.00	1.00
.981	.859	1.140	1.066	1.046	.95
.949	.789	1.184	1.088	1.032	.90
.906	.750	1.208	1.097	.994	.85
.859	.708	1.212	1.100	.945	.80
.806	.670	1.204	1.094	.882	.75
.748	.634	1.180	1.065	.812	.70
.688	.600	1.148	1.069	.736	.65
.627	.565	1.108	1.053	.660	.60
.564	.533	1.056	1.028	.580	.55
.500	.500	1.00	1.00	.500	.50
.435	.463	.940	.968	.421	.45
.373	.431	.864	.929	.347	.40
.311	.400	.776	.884	.275	.35
.252	.366	.688	.828	.208	.30
.194	.329	.588	.765	.148	.25
.141	.291	.484	.696	.098	.20
.094	.249	.376	.613	.057	.15
.051	.201	.255	.506	.026	.10
.019	.141	.135	.367	.007	.05
0.00	0.00	0.00	0.00	0.00	.00



AREA	WETTED PERIM.	H.M.D.	VELOCITY	DISCH.	DEPTH
1.00	1.00	1.00	1.00	1.00	1.00
.978	.862	1.109	1.053	1.027	.95
.937	.801	1.166	1.079	1.011	.90
.866	.752	1.176	1.083	.960	.85
.829	.709	1.166	1.079	.895	.80
.766	.668	1.145	1.068	.819	.75
.702	.629	1.114	1.054	.739	.70
.638	.591	1.077	1.036	.661	.65
.580	.553	1.046	1.021	.592	.60
.511	.514	.990	.993	.507	.55
.450	.476	.943	.971	.438	.50
.387	.436	.886	.939	.363	.45
.326	.397	.818	.906	.296	.40
.268	.357	.751	.866	.232	.35
.218	.317	.668	.816	.174	.30
.163	.277	.591	.766	.125	.25
.119	.238	.503	.708	.084	.20
.077	.193	.398	.630	.048	.15
.043	.148	.290	.540	.023	.10
.016	.100	.161	.400	.006	.05
0.00	0.00	0.00	0.00	0.00	.00

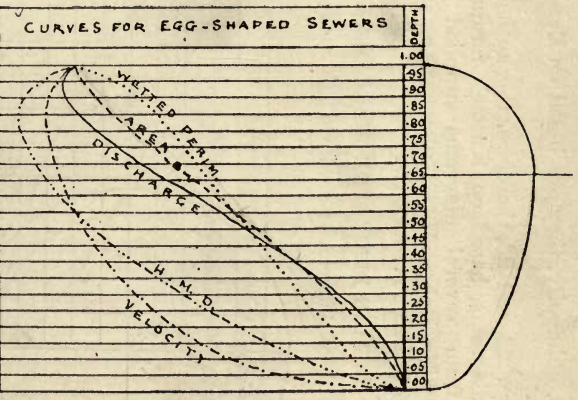


FIG. 21.

flow, but, unhappily, they are based on Eytelwein's formula.

In Figs. 22 and 23, therefore, the author gives similar diagrams, based on Kutter's formula, and derived from several diagrams supplied to the author by Mr. Robert Moore, M.AM.SOC.C.E., and Mr. Arthur L. Adams, M.AM.SOC.C.E.

SEWAGE DISCHARGE DIAGRAMS.

The bent of Americans towards labour and time

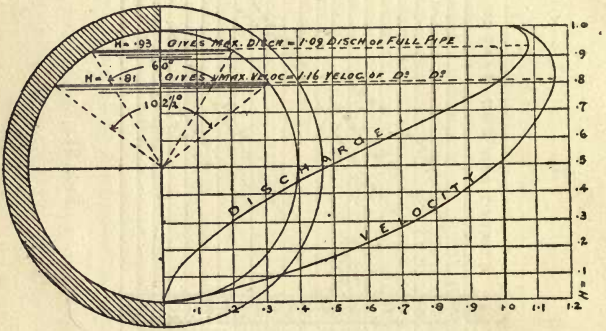


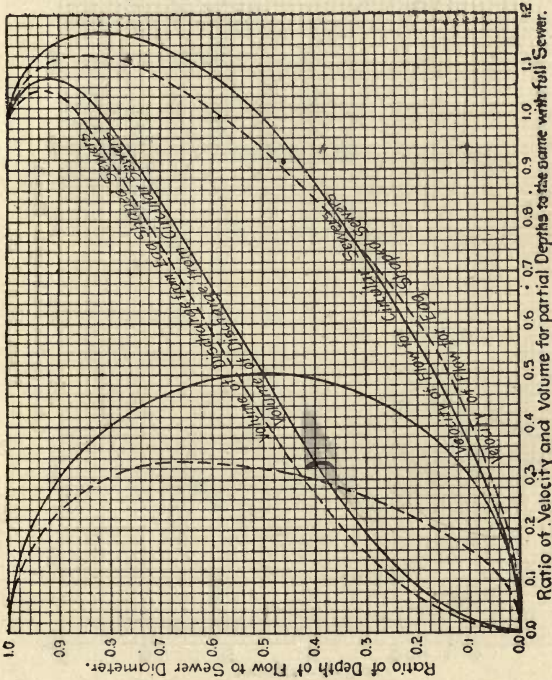
FIG. 22.

RATIOS OF VELOCITY AND DISCHARGE FOR CIRCULAR SEWERS PARTIALLY FULL TO SAME WHEN FULL.

This diagram is computed by Kutter's formula, and gives also the angle corresponding to the line of maximum velocity and maximum discharge.

saving appliances is well known, but few English engineers are probably aware to how wide an extent this tendency is manifesting itself in the American engineering profession by the conversion of formulæ and the reproduction of tables and data into handy

This diagram is computed by Kutter's formula. The height of the sewer and the volume of discharge and the velocity of flow with sewer running full are all taken as unity.



Ratios of Velocity and Discharge with Sewer partially full to the same when full.

Fig. 23.

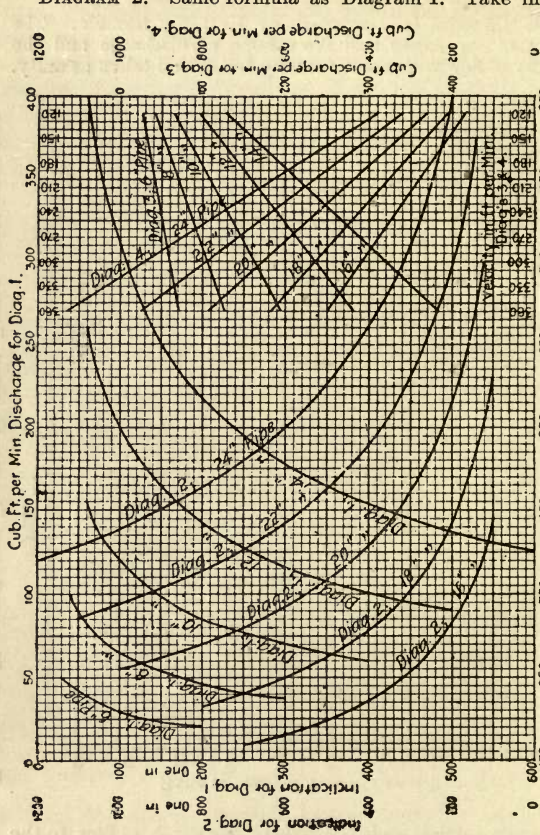
Find on vertical scale the ratio of the depth of flow to the sewer diameter and on the horizontal scale the ratio of the velocity and volume at that depth to the same when sewer is flowing full depth.

DIAGRAM 1.—Computed by Kutters' formula, with N = ·013. With N = ·012 add 10 per cent.

Take inclination on left hand vertical scale, and find discharge in cubic feet per minute on the top horizontal scale.

DIAGRAM 2.—Same formula as Diagram 1. Take inclination on left hand vertical scale and find discharge in cubic feet per minute on the bottom horizontal scale.

DIAGRAMS 3 and 4.—Take discharge in cubic feet per minute on right hand vertical scale and find velocity in feet per minute on the horizontal scale.


Cub. ft. Discharge per Min. for Diag. 4.
Cub. ft. Discharge per Min. for Diag. 3
Cub. ft. per Min. Discharge for Diag. 1.
Cub. ft. per Min. Discharge for Diag. 2.
Velocity in ft. per Min.
Inclination for Diag. 1
Inclination for Diag. 2
One in
Diag. 1
Diag. 2
Diag. 3
Diag. 4

FIGS. 24 and 25.

DISCHARGE AND VELOCITY OF FLOW IN 6-IN. TO 24-IN. PIPE SEWERS FLOWING FULL.

DIAGRAM 1.—Computed by Kutter's formula, with N = ·013. With N = ·015 deduct 18 per cent.

Take inclination on the right hand vertical scale and find discharge in cubic feet per minute on the bottom horizontal scale.

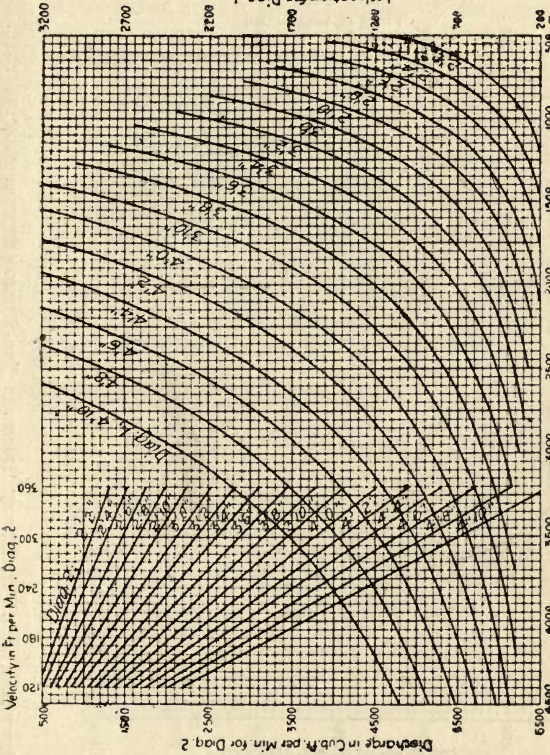

Inclination for Diag. 1.
Discharge in Cub. Ft. per Min. for Diag. 2
Velocity in Ft per Min. Diag. 2
Discharge in Cub. Ft per Min. for Diag. 1
Diag. 1
Diag. 2

FIG. 26.

DISCHARGE AND VELOCITY IN CIRCULAR SEWERS FLOWING FULL.

DIAGRAM 2.—Take discharge in cubic feet per minute on left hand vertical scale and find velocity in feet per minute on top horizontal scale.

DIAGRAM 1.—Computed by Kutter's formula, with N = ·103. With N = ·015 deduct 18 per cent.

Take inclination on the right hand vertical scale and find discharge in cubic feet per minute on the bottom horizontal scale.

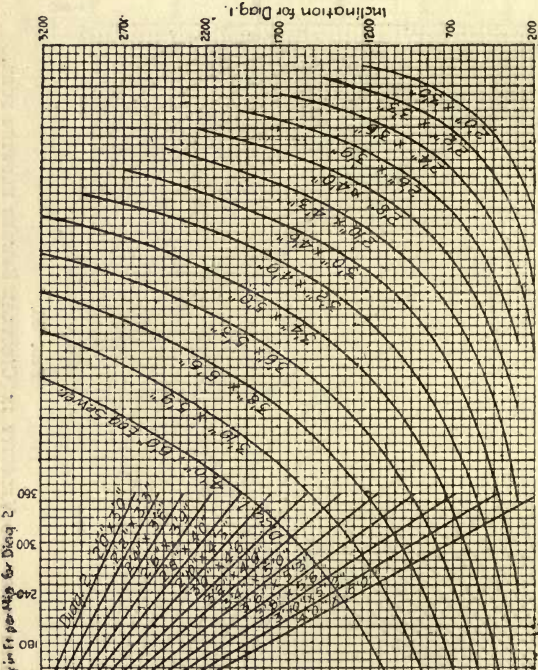

Inclination for Diag. 1.
Discharge in Cub. ft. per Min for Diag. 1.
Velocity in ft per Min for Diag. 2
Discharge in Cub. ft. per Min for Diag. 2.

FIG. 27.

DISCHARGE AND VELOCITY IN STANDARD EGG-SHAPED SEWERS FLOWING FULL.

DIAGRAM 2.—Take discharge in cubic feet per minute on left hand vertical scale and find velocity in feet per minute on top horizontal scale.

diagrams. Moreover, that section of the profession devoted to sewerage matters cannot complain of having been neglected in this respect, for they have been favoured with a large number of diagrams of sewer discharge. Nearly all these diagrams are plotted differently, and they each and all possess distinct advantages of their own.

The most handy diagrams—remarkable for compactness, combined with clearness, and fairly wide range—are those given in Figs. 24 to 27. Like Fig. 23, they are due to Mr. Arthur L. Adams. As it is generally of importance to know the velocity at a given inclination and discharge, the author believes that the ingenious method of plotting the velocities in the manner shown will be greatly appreciated. Though reduced to a somewhat small scale, the diagrams will be found sufficiently accurate for all but final calculations, and even for part of final work.

REESE LIBRARY OF THE UNIVERSITY

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Part 5.

THE RELATION BETWEEN RAINFALL AND SEWER DISCHARGE.

Part 5.

THE RELATION BETWEEN RAINFALL AND SEWER DISCHARGE.

In the modern combined system of sewerage—in which the sewers must take not only the sewage proper, but also the rainfall—it is of paramount importance to know exactly for what volume of rainfall provision should be made. The calculation of the volume of dry weather flow—*i.e.*, sewage proper—is a simple as well as comparatively unimportant matter, because the dry-weather flow is a known quantity, varying, it is true, between certain hours of the day, but, nevertheless, calculable within a considerable degree of accuracy; whilst rainfall is subject to such sudden fluctuations and bears such an enormously increased proportion to the dry-weather flow, that it really forms the governing factor in the design of sewers on the combined system. Having ascertained the quantity of water supplied per head of population and the density of population per acre, the flow of sewage proper is easily arrived at. But, on the other hand, if we attempt to answer the question, "What volume of rainfall will the sewers have to convey?" we are at once beset by innumerable difficulties. The consideration of the subject divides itself into two principal sections: (1) The actual rainfall on any given area or district; (2) the proportion of such rainfall which will reach the sewers.

RAINFALL STATISTICS.

The rainfall records of the British Isles are perhaps the most complete of any country, and are being perfected and amplified from year to year; but it may at once be stated that they are of comparatively little use to the sewerage engineer, inasmuch as they only give the total rainfall per twenty-four hours, and in a few instances for shorter periods. What he requires to know is not the total precipitation for lengthy periods, but the duration of heavy precipitations of short duration, as these alone tend to overtax the capacity of sewers, and therefore play a most important part in determining the size of the latter.

The Government supply marvellously accurate Ordnance maps, on which we can lay out sewerage systems with the greatest ease and expedition; they lend to public authorities the money necessary for carrying out such works, and exercise a benevolent control over the expenditure, so that the money shall be spent on efficient works. The Meteorological Office has a large staff of observers in every locality used to accurate observations; is it then asking too much that the existing staff might, at no great additional expense, be utilised to supply that information which is the very essence of the sewerage engineer's requirements—namely, rainstorm records? But if the Government cannot be prevailed upon to grant the above facilities, it remains for municipal engineers to urge their corporations to undertake the work of observation in their own particular locality. Every municipal community possessing, or likely to require, a sewerage system should be equipped with automatic recording rain gauges, to be distributed in suitable positions over the district, as sometimes

only portions of an entire district may be affected. At present we are somewhat groping in the dark, because there are few statistics to go upon. Of course it may be that some of our older engineers, if wise, have accumulated data which would be of value if communicated to the profession at large and tabulated in proper form; but the author believes that on the whole little has been done in this country to elucidate the subject. The sooner a systematic series of rain storm records is initiated the better, for, in order to allow of reliable deductions being made, they should embrace a period of many years.

SIZE OF SEWERS.

Although the whole volume of even heavy storms is easily carried off from a small area by an ordinary-sized drain, it is quite impracticable to build main outfall sewers of sufficient size to convey the discharge of the numerous tributaries comprising the network of a large drainage district, which may all be running full bore at the same time during a storm. A proportion of such rainfall must therefore be kept out of the main outlet sewers by the construction at suitable points of storm overflows discharging into natural watercourses.

Supposing now that we have obtained careful observations of the maximum rate of precipitation to be expected during heavy downpours in the locality for which we want to design a sewerage system, the question arises, "What proportion of the total volume will find its way into the sewers?" This depends to a large extent upon the nature of the surface, whether paved or unpaved, and if the latter, upon the degree of porosity of the ground. But there is another point that must be considered. Having arrived at the maximum rate of rainfall as

well as the proportion of same likely to be absorbed by the surface, we next have to enquire how quickly the remaining proportion will find its way into and become concentrated at the outlet. This will depend chiefly upon the size and configuration of the drainage area. Take the case where a heavy storm is bursting over a district. The steeper the slopes of the drainage valley the quicker will the discharge at the outlet reach a maximum. Further, the shorter the district in proportion to its breadth—*i.e.*, the shorter the time necessary for the water from the remotest parts of the district to travel to the outlet—the quicker will the maximum concentration at the outfall take place—*i.e.*, the quicker will all parts of the district contribute to the flow at the outfall. Mr. E. Kuichling, M.AM.SOC.C.E., city surveyor of Rochester, N.Y., one of the most able investigators of this problem of storm-water discharge in town sewers, has, from a large number of gaugings, devised a formula for proportioning the size of sewers, which embodies the expression of the relation of the probable maximum intensity of rainfall to its duration, and thus takes account of the time necessary for the storm wave to become concentrated to its maximum intensity.

But before giving Kuichling's formula it may be interesting to review some of the principal formulæ that have been proposed from time to time.

Probably the best known and most extensively used is that of the Swiss engineer, Burkli-Ziegler.

Burkli-Ziegler's formula :—

$$Q = C^4 \sqrt{\frac{S}{A}}$$

where Q = water reaching the sewer, cubic feet per second per acre.

R = average intensity of rain during the period of heaviest fall, in cubic feet per second per acre (found to vary from 1·75 to 2·75).
C = coefficient, varying from ·31 for rural districts to ·75 for paved and well-developed surfaces. Average value = ·625.
S = general slope of area per thousand.
A = area of drainage district in acres.

In this formula Q increases with R, C and S, and diminishes as A increases; but the formula takes no account of the shape of the watershed. It is, moreover, based on gaugings of comparatively small areas; hence, when applied to large areas it has generally proved unreliable.

Hawksley and Bazalgete adopted the following formula:—

$$\text{Log. } D = \frac{3 \text{ Log. } A + \text{Log. } N + 6{\cdot}8}{10}$$

where D = diameter of circular sewer in inches, to carry off a rainfall of 1 in. per hour.
A = number of acres drained.
N = length of feet in which the sewer falls 1 ft.

This formula contains only two variables—the area and the slope—without taking account of any of the other functions entering into the problem, and, besides, only allows for a maximum rainfall of 1 in. per hour. It is, therefore, not surprising that in a number of cases where sewers have been proportioned by this formula additional relief sewers have had to be constructed subsequently.

Colonel Adams' formula, as simplified by Kuichling, reads:—

$$Q = 1{\cdot}035\ A\ r \sqrt[12]{\frac{S}{A^2\ r^2}}$$

where Q = maximum discharge of outlet sewer, cubic feet per second.
r = rate of rainfall, 1 in. per hour.
S = sine of general slope of surface of district.

McMath, of St. Louis, next proposed the following:

$$Q = C\,R\sqrt[5]{S\,A^4}$$

where Q = cubic feet per second discharge from whole area drained.

C = proportion of total rainfall that will reach the sewers, the value of which will, of course, depend principally upon the nature of the surface, varying from about 95 per cent for paved city districts to as low as 25 per cent. for undeveloped suburban areas.

R = cubic feet of water falling upon an acre of surface per second during the period of greatest intensity of rain, which is practically the same as the rate of rainfall in inches per hour.

S = mean slope of surface per thousand.

For paved city surfaces Mr. McMath found that the quantity of water reaching the sewers may be computed by writing the formula

$$Q = 2{\cdot}0625\sqrt[5]{S\,A^4}$$

Looking at the heterogeneous constitution of these various formulæ, it is not surprising to find that if applied to the same sewer problem they should give results differing to such an extent as to cause grave doubts as to the possibility of devising any formula that will adapt itself to all the varying conditions underlying the relation between rainfall and sewer discharge. Capt. R. L. Hoxie, M.A.M.SOC.C.E., rightly says: "It requires no argument to point out the impracticability of such generalisations as are involved in empirical formulæ for maximum flood flow. They are useful, as each suggests its relation to the cases to which it is made to conform, and so widens the field explored; but there is no legerdemain in hydraulics which can solve a problem of

twenty independent variables by the use of one or two. These empirical formulæ, which can only be applied with confidence within the limits of the experiments on which they are based, are too often mistaken for devices by which a few hours of elementary computation may suffice instead of laborious thought and thoroughness of investigation."

Having thus seen that there is no royal road, no simple universal formula, for accurately proportioning the size of sewers in relation to rainfall, let us once more refer to Mr. Kuichling's experiments and investigations, above alluded to. The principal conclusions at which he arrived may be summarised as follows:—

(1.) The percentage of the rainfall discharged from any given drainage area by the sewers during the period of maximum flow is nearly constant for rains of considerable intensities and lasting equal periods of time. In other words, supposing we have a drainage area of 300 acres, and supposing that during the period of maximum flow produced by a rainfall of $\frac{1}{4}$ in. per hour lasting twenty minutes—say 35 per cent. of the whole rainfall is discharged—then during a rainfall of 1 in. per hour lasting an equal time—*viz.*, twenty minutes—the percentage of discharge would also be about 35 per cent.

(2.) The said percentage varies directly with the degree of urban development of the district—*viz.*, with the amount of impervious surface thereon.

(3.) The said percentage increases rapidly and directly or uniformly with the duration of maximum intensity of rainfall, until a period is reached which is equal to the time required for the concentration of the drainage waters from the entire tributary area.

(4.) The said percentage becomes larger when a moderate rain has immediately preceded a heavy shower, thereby partially saturating the permeable territory and correspondingly increasing the extent of impervious surface.

The above conclusions, further, led Mr. Kuichling to the opinion that, "Instead of employing any of the known formulæ, the safer method will be to estimate the probable future amount of impervious surface on the given area, either with reference to the density of population or in any more reliable manner that may be devised, and to assume that all water falling on paved surfaces will run off without loss. Further, since the topography of the area is supposed to be known, the slopes and length of the longest tributaries to the outlet sewer can readily be determined, as well as their approximate diameters, and thence also the velocities of flow therein. From these elements the time required for the flood waters to reach the outlet sewer from the most distant parts in the area can next be found; and when the relation between the probable maximum intensity of the rain and its corresponding duration are known, the maximum rate of rainfall belonging to the time so found can then be deduced. The dimensions of a sewer so computed will be found adequate until the original assumed amount of impervious surface, or density of population, has been exceeded."

From the above considerations Mr. Kuichling has evolved a formula which, if judiciously employed in combination with the above method of reasoning, must be regarded as embodying the latest advance in this complicated problem of storm-water discharge.

Kuichling's formula reads :—

$$Q = A\,a\,t\,(b - c\,t).$$

where Q = sewer discharge, cubic feet per second.

A = magnitude of drainage area.

a, b, c = certain empirical constants deduced from the relation of the maximum intensity of rainfall to its duration. These constants will vary for different localities.

t = time required for the concentration of the storm water at the outlet.

In conclusion, the author ventures to express a hope that English engineers may soon take the lead in investigations of sewerage problems, which for the time being they seem to have relinquished to their American *confrères*. The installing of numerous automatic recording rain gauges is a *sine quâ non* to the attainment of this object. Equally necessary, perhaps even more so, is the fixing of automatic recording storm gauges in the sewers themselves, so that the actual rainfall and the actual discharge of the sewers may be compared without the element of uncertainty which is bound to be associated with gaugings conducted without the aid of automatic instruments of precision. Storms have a way of bursting over a district just when they are least expected, and some of the best records may be lost unless automatic gauges are resorted to.

APPENDIX.

APPENDIX.

It has already been pointed out in a previous chapter that from the general formula

$$V = c\sqrt{R \times S}$$

the following formulæ are deduced:—

For velocity

$$V = c\sqrt{R} \times \sqrt{S} \quad (1)$$

$$c\sqrt{R} = \frac{V}{\sqrt{S}} \quad (2)$$

$$\sqrt{S} = \frac{V}{c\sqrt{R}} \quad (3)$$

and, further, as $Q = A \times V$, therefore

For discharge

$$Q = (A \times c\sqrt{R}) \times \sqrt{S} \quad (4)$$

$$(A \times c\sqrt{R}) = \frac{Q}{\sqrt{S}} \quad (5)$$

$$\sqrt{S} = \frac{Q}{(A \times c\sqrt{R})} \quad (6)$$

The above six formulæ are readily applied to the solution of the following six problems, frequently occurring in sewerage calculations:—

Formula.	Required.	Problem. Given.
(1)	Velocity.	Diameter and Inclination.
(2)	Diameter.	Velocity and Inclination.
(3)	Inclination.	Diameter and Velocity.
(4)	Discharge.	Diameter and Inclination.
(5)	Diameter.	Discharge and Inclination.
(6)	Inclination.	Diameter and Discharge.

EXAMPLES SHOWING APPLICATION OF THE TABLES.

Example No. 1.

Find Velocity (given *Diameter* and *Inclination*).—A glazed stoneware pipe sewer, 18 in. diameter, has an inclination of 1 in 232. Find velocity of sewer when flowing full, also when quarter full. Take $n = \cdot 012$.

By formula (1) $V = c\sqrt{R} \times \sqrt{S}$

Then (by Table V.) $c\sqrt{R}$ for an 18-in. pipe. with $n = \cdot 012$ equals 63·83

Further (by Table XI.), $\sqrt{S}$ for 1 in 232 = ·065653

And 63·83 × ·065653 = 4·19 ft. per second velocity, flowing full

Also (by Table A, Part IV., p. 52, *Kutter*) velocity quarter full = ·66 × velocity full, tberefore 4·19 × ·66 = 2·76 ft. per second velocity when quarter full.

Example No. 2.

Find Diameter (given *Velocity* and *Inclination*).—A standard egg-shape brick sewer is to have an inclination of 1 in 519, and the velocity when flowing two-thirds full is not to exceed 6 ft. per second. Find the diameter. Take $n = \cdot 015$.

By formula (2) $c\sqrt{R} = \frac{V}{\sqrt{S}}$

Then (by Table XI.) $\sqrt{S}$ for 1 in 519 = ·043895

and $\frac{V}{\sqrt{S}} = \frac{6}{·043895} = 136·7$

Searching in Table IX. under $c\sqrt{R}$ for two-thirds full we find the value nearest to 136·7 to be opposite diameter 5 ft. × 7 ft. 6 in., which is the required diameter.

EXAMPLE No. 3.

Find Inclination (given *Diameter* and *Velocity*).—A cast-iron circular sewer is to be 5 ft. 8 in. diameter, and to have a maximum velocity of 6 ft. per second flowing full. Find the inclination. Take $n = ·015$.

By formula (3) $\sqrt{S} = \frac{V}{c\sqrt{R}}$

Then (by Table VI.) $c\sqrt{R}$ for 5 ft. 8 in. diameter and $n = ·015$ equals 126, and $\frac{V}{c\sqrt{R}} = \frac{6}{126} = ·047619$

Searching in Table XI. under $\sqrt{S}$ we find the nearest valve to ·047619 to be opposite 1 in 441, which is the required inclination.

EXAMPLE No. 4.

Find Discharge (given *Diameter* and *Inclination*).—A new egg-shape concrete sewer, 2 ft. × 3 ft. diameter, is to have an inclination of 1 in 475. Find the discharge when flowing one-third full. Take $n = ·015$.

By formula (4) $Q = (A \times c\sqrt{R}) \times \sqrt{S}$

Then (by Table X.) $(A \times c\sqrt{R})$ for 2 ft. × 3 ft. diameter and one-third full equals 50·17

Further (By Table XI.) $\sqrt{S}$ for 1 in 475 = ·045883 and 50·17 × ·045883 = 2·30 cubic feet per second, the discharge.

EXAMPLE No. 5.

Find Diameter (given *Discharge* and *Inclination*).—A glazed stoneware pipe sewer is to discharge 11½ cubic feet per second flowing full, and to have an inclination of 1 in 280. Find the diameter. Take $n = \cdot013$.

By formula (5) $(A \times c\sqrt{R}) = \dfrac{Q}{\sqrt{S}}$

Then (by Table XI.) $\sqrt{S}$ for 1 in 280 $= \cdot059761$ and

$$\frac{Q}{\sqrt{S}} = \frac{11{\cdot}5}{\cdot059761} = 192{\cdot}44$$

Searching in Table V., under $(A \times c\sqrt{R})$ and under ·013, we find the nearest value to 192·44 to be opposite 23 in., which is the required diameter. Say 24-in. pipe.

EXAMPLE No. 6.

Find Inclination (given *Diameter* and *Discharge*).—A standard egg-shape brick sewer, 4 ft. by 6 ft. diameter, is to discharge 70 cubic feet per second flowing full. Find inclination. Take $n = \cdot015$.

By formula (6) $\sqrt{S} = \dfrac{Q}{(A \times c\sqrt{R})}$

Then (by Table IX.) $(A \times c\sqrt{R})$ for sewer, 4 ft. × 6 in. diameter, flowing full = 2019·5 and

$$\frac{Q}{(A \times c\sqrt{R})} = \frac{70}{2019{\cdot}5} = \cdot03466$$

Searching in Table XI., under $\sqrt{S}$, we find the nearest value to ·03466 to be opposite 1 in 832, which is the required inclination.

Table V.

For *Pipe* Sewers, 6 in. to 24 in. diameter, flowing *full*.

$$V \text{ (feet per second)} = c\sqrt{R} \times \sqrt{S}$$

$$Q \text{ (cubic feet per second)} = (A \times c\sqrt{R}) \times \sqrt{S}$$

Diam.	A	R	$\sqrt{R}$	$c\sqrt{R}$ (for Velocity.)			$A \times c\sqrt{R}$ (for Discharge.)		
	Sect. Area.	(H.M.D.)							
in.	sq. ft.	ft.	ft.	$n = \cdot011$	$n = \cdot012$	$n = \cdot013$	$n = \cdot011$	$n = \cdot012$	$n = \cdot013$
6	·196	·125	·354	30 93	27·54	24·60	6·06	5·38	4·82
7	·267	·146	·382	34·94	31·05	27·87	9·33	8·29	7·44
8	·349	·167	·408	38·77	34·51	31·00	13·53	12·04	10·82
9	·442	·187	·433	42·40	37·80	34·00	18·74	16·71	15·03
10	·545	·208	·456	45·83	40·95	36·87	24·98	22·32	20·09
11	·660	·229	·479	49·46	44·22	39·84	32·64	29·18	26·30
12	·785	·250	·500	52·85	47·30	42·65	41·49	37·15	33·50
13	·922	·271	·520	55·95	50·11	45·22	51·59	46·20	41·69
14	1·069	·292	·540	59·13	52·99	47·85	63·21	56·64	51·16
15	1·227	·312	·559	62·22	55·78	50·42	76·35	68·44	61·87
16	1·396	·333	·577	65·21	58·50	52·90	91·04	81·66	73·85
17	1·576	·354	·595	68·26	61·26	55·44	107·6	96·55	87·37
18	1 767	·375	·612	71·08	63·83	57·80	125·6	112·8	102·1
19	1·969	·396	·629	73·90	66·41	60·17	145·5	130·8	118·5
20	2·182	·417	·646	76·76	69·03	62·58	167·5	150·6	136·5
21	2·405	·437	·661	79·33	71·38	64·73	190·8	171·7	155·7
22	2·640	·458	·677	82·11	73·92	67·07	216·8	195·1	177·1
23	2·885	·479	·692	84·75	76·33	69·29	244·5	220·2	199·9
24	3·142	·500	·707	87 36	78·72	71·49	274·5	247·3	224·6

Table VI.

For *Circular* Sewers, 2 ft. to 12 ft. diameter, flowing *full*.

$$V \text{ (feet per second)} = c\sqrt{R} \times \sqrt{S}$$

$$Q \text{ (cubic feet per second)} = (A \times c\sqrt{R}) \times \sqrt{S}$$

Diam.		A Sect. Area.	R (H.M.D.)	$\sqrt{R}$	$c\sqrt{R}$ (for Velocity).		$A \times c\sqrt{R}$ (for Discharge).	
ft.	in.	sq. ft.	ft.	ft.	$n = .013$	$n = .015$	$n = .013$	$n = .015$
2	0	3·14	·500	·707	71·5	60·1	224·6	188·8
2	1	3·41	·521	·722	73·7	61·9	251·1	211·2
2	2	3·69	·542	·736	75·7	63·7	279·1	234·9
2	3	3·98	·562	·750	77·8	65·5	309·2	260·5
2	4	4·28	·583	·764	79·9	67·3	341·5	287·9
2	5	4·59	·604	·777	81·8	69·0	375·4	316·6
2	6	4·91	·625	·790	83·8	70·7	411·3	347·3
2	7	5·24	·648	·804	85·9	72·6	450·5	380·5
2	8	5·58	·667	·817	87·9	74·3	490·9	414·8
2	9	5·94	·687	·829	89·7	76·0	532·8	451·2
2	10	6·30	·708	·842	91·7	77·6	578·0	489·0
2	11	6·68	·729	·854	93·5	79·2	624·8	528·8
3	0	7·07	·750	·866	95·4	80·8	674·1	570·9
3	1	7·47	·771	·878	97·2	82·4	726·0	615·1
3	2	7·87	·792	·890	99·1	84·0	780·6	661·8
3	3	8·29	·812	·901	100·9	85·5	836·7	709·6
3	4	8·73	·833	·913	102·8	87·1	896·3	760·4
3	5	9·17	·854	·924	104·4	88·6	957·3	812·4
3	6	9·62	·875	·935	106·1	90·1	1021·1	866·9
3	7	10·08	·896	·946	107·9	91·6	1087·7	923·7
3	8	10·56	·917	·957	109·6	93·1	1157·2	983·1

Diam.	A Sect. Area.	R (H.M. D.)	$\sqrt{R}$	$c\sqrt{R}$ (for Velocity.)		$A \times c\sqrt{R}$ (for Discharge.)	
ft. in.	sq. ft.	ft.	ft.	$n = .013$	$n = .015$	$n = .013$	$n = .015$
3 9	11·04	·937	·968	111·3	94·6	1229·7	1045·0
3 10	11·54	·958	·979	113·1	96·1	1305·3	1109·6
3 11	12·05	·979	·990	114·9	97·5	1384·1	1175·2
4 0	12·57	1·000	1·000	116·5	99·1	1463·9	1245·3
4 1	13·10	1·021	1·010	118·1	100·5	1546·9	1315·8
4 2	13·63	1·042	1·021	119·8	102·0	1633·5	1390·8
4 3	14·19	1·062	1·031	121·4	103·4	1722·0	1466·7
4 4	14·75	1·083	1·041	123·0	104·8	1813·8	1545·7
4 5	15·32	1·104	1·051	124·6	106·2	1908·0	1627·0
4 6	15·90	1·125	1·061	126·2	107·6	2007·0	1711·4
4 7	16·50	1·146	1·070	127·7	108·9	2206·1	1796·5
4 8	17·10	1·167	1·080	129·3	110·3	2211·1	1886·8
4 9	17·72	1·187	1·089	130·7	111·6	2316·9	1977·7
4 10	18·39	1·208	1·099	132·4	113·0	2429·1	2074·1
4 11	18·99	1·229	1·109	134·0	114·4	2543·9	2172·9
5 0	19·63	1·250	1·118	135·4	115·7	2659·0	2272·7
5 1	20·20	1·271	1·127	136·9	117·1	2778·7	2376·7
5 2	20·97	1·292	1·137	138·5	118·4	2903·5	2482·0
5 3	21·65	1·312	1·146	139·9	119·7	3029·4	2590·5
5 4	22·34	1·333	1·155	141·4	121·0	3159·0	2702·1
5 5	23·04	1·354	1·164	142·9	122·2	3292·3	2816·7
5 6	23·76	1·375	1·173	144·3	123·5	3429·2	2934·8
5 7	24·48	1·396	1·181	145·6	124·8	3566·2	3056·4
5 8	25·22	1·417	1·190	147·1	126·0	3710·9	3177·3
5 9	25·97	1·437	1·199	148·6	127 3	3859·7	3305·6
5 10	26·73	1·458	1·208	150·1	128·6	4012·2	3436·3
5 11	27·49	1·479	1·216	151·4	129·7	4162·7	3566·6
6 0	28·27	1·500	1·225	152·9	131·0	4322·9	3702·3
6 3	30·68	1·562	1·250	157·0	134·6	4816·8	4130·3
6 6	33·18	1·625	1·275	161·2	138·3	5339 7	4588·3
6 9	35·78	1·687	1·299	165·2	141·8	5911·5	5074 7
7 0	38·48	1·750	1·323	169·2	145·3	6510·6	5591·6
7 3	41·28	1·812	1·346	173·0	148·7	7142·0	6136 8
7 6	44·18	1·879	1·369	176·9	152·0	7814·2	6717·0
7 9	47·17	1·937	1·392	180·8	155·5	8527·9	7333·5
8 0	50·27	2·000	1·414	184·5	158·7	9272 6	7978·3

Diam.		A Sect. Area.	R (H.M.D.)	$\sqrt{R}$	$c\sqrt{R}$ (for Velocity.)		$A \times c\sqrt{R}$ (for Discharge.)	
ft.	in.	sq. ft.	ft.	ft.	$n = \cdot013$	$n = \cdot015$	$n = \cdot013$	$n = \cdot015$
8	3	53·46	2·062	1·436	188 2	162·0	10059	8658·8
8	6	56·74	2·125	1·458	191·9	165·3	10889	9377·9
8	9	60·13	2·187	1·479	195·4	168 4	11753	10128
9	0	63·62	2·250	1·500	199·1	171·6	12663	10917
9	3	67·20	2·312	1·521	202·6	174·7	13613	11740
9	6	70·88	2·375	1·541	205·9	177·7	14597	12594
9	9	74·66	2·437	1·561	209·3	180·7	15629	13489
10	0	78·54	2·500	1·581	212·8	183·7	16709	14426
10	3	82·52	2·562	1·601	216·2	186·7	17837	15406
10	6	86·59	2·625	1·620	219·4	189·5	18996	16412
10	9	90·76	2·687	1·639	222·6	192·4	20205	17462
11	0	95·03	2·750	1·658	225 9	195·2	21464	18555
11	3	99·40	2·812	1·677	229·1	198·1	22774	19694
11	6	103·9	2·875	1·696	232·4	201·0	24139	20879
11	9	108·4	2·937	1·714	235·4	203·7	25533	22093
12	0	113 1	3·000	1·732	238·6	206 5	26981	23352

TABLE VII.

A (Area), R (H.M.D.) and $\sqrt{R}$ of *Standard Egg-Shape* Sewers,

2 ft. × 3 ft. to 6 ft. × 9 ft. diameter.

Dimensions.	Full.			⅔ Full.			⅓ Full.		
	A (Area.)	R (H.M.D.)	$\sqrt{R}$	A (Area.)	R (H.M.D.)	$\sqrt{R}$	A (Area.)	R (H.M.D.)	$\sqrt{R}$
ft. in. ft. in.	sq. ft.	ft.	ft.	sq. ft.	ft.	ft.	sq. ft.	ft.	ft.
2 0 × 3 0	4·59	·579	·761	3·02	·631	·794	1·14	·413	·643
2 2 × 3 3	5·39	·628	·792	3·55	·684	·827	1·33	·448	·669
2 4 × 3 6	6·25	·676	·822	4·11	·737	·858	1·55	·482	·693
2 6 × 3 9	7·18	·724	·851	4·72	·789	·888	1·78	·517	·719
2 8 × 4 0	8·17	·772	·879	5·37	·842	·918	2·02	·551	·742
2 10 × 4 3	9·22	·821	·906	6·07	·894	·945	2·28	·585	·765
3 0 × 4 6	10·34	·869	·932	6·80	·947	·973	2·56	·620	·787

Dimensions.	Full.			⅔ Full.			⅓ Full.		
	A (Area).	R (H.M.D.)	$\sqrt{R}$	A (Area).	R (H.M.D.)	$\sqrt{R}$	A (Area).	R (H.M.D.)	$\sqrt{R}$
ft. in. ft. in.	sq. ft.	ft.	ft.	sq. ft.	ft.	ft.	sq. ft.	ft.	ft.
3 2 × 4 9	11·52	·917	·958	7·58	1·000	1·000	2·85	·654	·809
3 4 × 5 0	12·76	·966	·983	8·40	1·052	1·026	2·16	·689	·830
3 6 × 5 3	14·07	1·014	1·007	9·29	1·105	1·051	3·48	·723	·850
3 8 × 5 6	15·44	1·062	1·030	10·16	1·158	1·076	3·82	·758	·871
3 10 × 5 9	16·88	1·111	1·054	11·11	1·210	1·100	4·17	·792	·890
4 0 × 6 0	18·38	1·159	1·077	12·09	1·263	1·124	4·54	·826	·909
4 2 × 6 3	19·94	1·207	1·099	13·12	1·315	1·147	4·93	·861	·928
4 4 × 6 6	21·57	1·255	1·120	14·19	1·368	1·170	5·33	·895	·946
4 6 × 6 9	23·26	1·304	1·142	15·30	1·421	1·192	5·75	·930	·964
4 8 × 7 0	25·01	1·352	1·163	16·46	1·473	1·214	6·18	·264	·982
4 10 × 7 3	26·83	1·400	1·183	17·66	1·526	1·235	6·63	·999	·999
5 0 × 7 6	28·71	1·449	1·204	18·89	1·579	1·257	7·10	1·033	1·016
5 2 × 7 9	30·66	1·497	1·223	20·18	1·631	1·277	7·58	1·068	1·033
5 4 × 8 0	32·67	1·545	1·243	21·50	1·684	1·298	8·08	1·102	1·050
5 6 × 8 3	34·74	1·593	1·262	22·86	1·736	1·318	8·59	1·136	1·066
5 8 × 8 6	36·88	1·642	1·282	24·27	1·789	1·338	9·12	1·171	1·082
5 10 × 8 9	39·08	1·690	1·300	25·72	1·842	1·357	9·66	1·205	1·098
6 0 × 9 0	41·35	1·738	1·318	27·21	1·894	1·376	10·22	1·240	1·114

TABLE VIII.

A (Area), R (H.M.D.) and $\sqrt{R}$ of *Standard Egg-Shape* Sewers,

2 ft. × 3 ft. to 6 ft. × 9 ft. diameter.

Dimensions.	Full.			½ Full.			¼ Full.		
	A (Area).	R (H.M.D.)	$\sqrt{R}$	A (Area).	R (H.M.D.)	$\sqrt{R}$	A (Area).	R (H.M.D.)	$\sqrt{R}$
ft. in. ft. in.	sq. ft.	ft.	ft.	sq. ft.	ft.	ft.	sq. ft.	ft.	ft.
2 0 × 3 0	4·46	·569	·754	2·80	·615	·784	1·02	·384	·620
2 2 × 3 3	5·23	·616	·785	3·39	·666	·816	1·19	·416	·645
2 4 × 3 6	6·07	·664	·815	3·93	·717	·847	1·38	·448	·670
2 6 × 3 9	6·97	·711	·843	4·51	·768	·876	1·59	·480	·693
2 8 × 4 0	7·93	·758	·871	5·14	·820	·905	1·81	·512	·716
2 10 × 4 3	8·95	·806	·897	5·80	·871	·933	2·04	·544	·739
3 0 × 4 6	10·03	·853	·924	6·50	·922	·260	2·29	·576	·759

Dimensions.	Full.			⅔ Full.			⅓ Full.		
	A (Area).	R (H.M.D.)	$\sqrt{R}$	A (Area).	R (H.M.D.)	$\sqrt{R}$	A (Area).	R (H.M.D.)	$\sqrt{R}$
ft. in. ft. in.	sq. ft.	ft.	ft.	sq. ft.	ft.	ft.	sq. ft.	ft.	ft.
3 2 × 4 9	11·18	·901	·949	7·24	·973	·987	2·55	·608	·780
3 4 × 5 0	12·39	·948	·974	8·03	1·025	1·012	2·83	·640	·800
3 6 × 5 3	13·66	·995	·998	8·85	1·076	1·037	3·11	·672	·820
3 8 × 5 6	14·99	1·043	1·021	9·71	1·127	1·062	3·42	·704	·839
3 10 × 5 9	16·38	1·090	1·044	10·61	1·178	1·086	3·74	·736	·858
4 0 × 6 0	17·84	1·138	1·066	11·56	1·230	1·109	4·07	·768	·876
4 2 × 6 3	19·36	1·185	1·089	12·54	1·281	1·132	4·41	·800	·895
4 4 × 6 6	20·94	1·232	1·110	13·56	1·332	1·154	4·77	·832	·912
4 6 × 6 9	22·58	1·280	1·131	14·63	1·383	1·176	5·15	·864	·930
4 8 × 7 0	24·28	1·327	1·152	15·73	1·434	1·198	5·54	·896	·947
4 10 × 7 3	26·05	1·375	1·173	16·87	1·486	1·219	5·94	·928	·963
5 0 × 7 6	27·87	1·422	1·193	18·06	1·537	1·240	6·36	·960	·980
5 2 × 7 9	29·76	1·469	1·212	19·28	1·588	1·261	6·79	·992	·996
5 4 × 8 0	31·71	1·517	1·231	20·54	1·639	1·281	7·23	1·024	1·012
5 6 × 8 3	33·73	1·564	1·251	21·85	1·691	1·300	7·69	1·056	1·028
5 8 × 8 6	35·80	1·612	1·269	23·19	1·742	1·320	8·17	1·088	1·043
5 10 × 8 9	37·94	1·659	1·288	24·58	1·793	1·339	8·65	1·120	1 058
6 0 × 9 0	40·14	1·706	1·306	26·00	1·844	1·358	9·15	1·152	1·073

Table IX.

For Velocity and Discharge of *Standard Egg-Shape* Sewers.

2 ft. × 3 ft. to 6 ft. × 9 ft. diameter.

V (feet per second) $= c\sqrt{R} \times \sqrt{S}$

Q (cubic feet per second) $= (A \times c\sqrt{R}) \times \sqrt{S}$

Dimensions.						Full.			
						$c\sqrt{R}$ (for Velocity).		$A \times c\sqrt{R}$ (for Discharge).	
ft.	in.		ft.	in.		$n = 0.013$	$n = 0.015$	$n = 0.013$	$n = 0.015$
2	0	×	3	0		79·4	66·9	364·8	307·5
2	2	×	3	3		84·1	71·0	453·6	382·8
2	4	×	3	6		88·6	74·9	554·3	468·5
2	6	×	3	9		93·1	78·8	668·0	565·3
2	8	×	4	0		97·4	82·4	795·5	673·3
2	10	×	4	3		101·6	86·2	937·1	794·9
3	0	×	4	6		105·6	89·7	1092·2	927·2
3	2	×	4	9		109·7	93·2	1264·1	1074·0
3	4	×	5	0		113·7	96·7	1451·6	1234·4
3	6	×	5	3		117·6	100·1	1654·5	1407·6
3	8	×	5	6		121·4	103·4	1874·5	1596·7
3	10	×	5	9		125·1	106·6	2110·8	1799·1
4	0	×	6	0		128·8	109·9	2366·6	2019·5
4	2	×	6	3		132·4	113·0	2639·8	2254·0
4	4	×	6	6		135·7	116·0	2927·5	2501·4
4	6	×	6	9		139·3	119·1	3239·6	2770·0
4	8	×	7	0		142·7	122·1	3569·6	3053·8
4	10	×	7	3		146·0	125·0	3917·0	3353·0
5	0	×	7	6		149·4	128·0	4291·2	3675·6
5	2	×	7	9		152·5	130·7	4677·4	4007·9
5	4	×	8	0		155·8	133·6	5091·4	4364·9
5	6	×	8	3		159·0	136·4	5523·7	4738·0
5	8	×	8	6		162·1	139·2	5980·5	5131·7
5	10	×	8	9		165·3	142·0	6462·4	5548·0
6	0	×	9	0		168·3	144·6	6960·1	5980·3

STANDARD EGG-SHAPE SEWERS *(continued)*.

Dimensions.				¾ Full.			
				$c\sqrt{R}$ (for Velocity).		$A \times c\sqrt{R}$ (for Discharge).	
ft.	in.	ft.	in.	n=·013	n=·015	n=·013	n=·015
2	0 ×	3	0	84·6	71·4	255·7	216·5
2	2 ×	3	3	89·4	75·6	317 2	268·2
2	4 ×	3	6	94·1	79·7	387·4	327·9
2	6 ×	3	9	99·0	83·9	467·5	396·3
2	8 ×	4	0	103·5	87·8	556·2	472·0
2	10 ×	4	3	107·8	91 6	654·4	555·7
3	0 ×	4	6	112·1	95·3	762·8	648·4
3	2 ×	4	9	116·5	99·1	882·9	751·1
3	4 ×	5	0	120·6	102·7	1012·7	862·4
3	6 ×	5	3	124·6	106·2	1153·4	983·2
3	8 ×	5	6	128·6	109·7	1307·0	1115·1
3	10 ×	5	9	132·5	113 2	1472·1	1256·1
4	0 ×	6	0	136·4	116·5	1649·3	1409·4
4	2 ×	6	3	140·1	119·8	1838·5	1572·1
4	4 ×	6	6	143·8	123·1	2041·5	1746·9
4	6 ×	6	9	147·5	126·3	2257·1	1932·7
4	8 ×	7	0	151·1	129·4	2486·8	2130·5
4	10 ×	7	3	154·5	132·5	2728·3	2338·6
5	0 ×	7	6	158·0	135·5	2985·4	2560·3
5	2 ×	7	9	161·5	138·6	3258·4	2795·9
5	4 ×	8	0	165·0	141·7	3547·8	3045 5
5	6 ×	8	3	168·3	144·6	3848·8	3305·3
5	8 ×	8	6	171·7	147·5	4166 3	3578·9
5	10 ×	8	9	174·8	150·3	4496·8	3864·8
6	0 ×	9	0	178·0	153·1	4844·9	4165·3

STANDARD EGG-SHAPE SEWERS (*continued*).

Dimensions.				½ Full.			
				$c\sqrt{R}$ (for Velocity).		$A \times c\sqrt{R}$ (for Discharge).	
ft.	in.		ft. in.	$n = ·013$	$n = ·015$	$n = ·013$	$n = ·015$
2	0	×	3 0	62·1	52·1	70·6	59·2
2	2	×	3 3	65·9	55·3	87·8	73·7
2	4	×	3 6	69·7	58·6	107·8	90·6
2	6	×	3 9	73·2	61·6	130·0	109·4
2	8	×	4 0	76·6	64·5	154·7	130·3
2	10	×	4 3	80·0	67·5	182·4	153·8
3	0	×	4 6	83·5	70·5	213·5	180·1
3	2	×	4 9	86·7	73·2	246·9	208·6
3	4	×	5 0	89·8	76·0	283·6	239·8
3	6	×	5 3	92·9	78·6	323·2	273·5
3	8	×	5 6	96·0	81·3	366·5	310·4
3	10	×	5 9	99·1	84·0	413·7	350·7
4	9	×	6 0	102·1	86·6	463·9	393·6
4	2	×	6 3	105·0	89·0	517·9	438·7
4	4	×	6 6	107·8	91·6	575·2	488·5
4	6	×	6 9	110·7	94·1	636·6	541·0
4	8	×	7 0	113·6	96·6	702·5	597·3
4	10	×	7 3	116·5	99·1	772·9	657·5
5	0	×	7 6	119·0	101·3	845·0	719·3
5	2	×	7 9	121·7	103·7	922·7	785·9
5	4	×	8 0	124·4	106·1	1005·1	856·7
5	6	×	8 3	127·0	108·3	1091·1	930·5
5	8	×	8 6	129·6	110·6	1181·9	1008·7
5	10	×	8 9	132·2	112·9	1277·8	1091·0
6	0	×	9 0	134·6	115·0	1376·4	1175·8

Table X.

For Velocity and Discharge of *New Egg-Shape* Sewers.

2 ft. × 3 ft. to 6 ft. × 9 ft. diameter.

V (feet per second) $= c\sqrt{R} \times \sqrt{S}$

Q (cubic feet per second) $= (A \times c\sqrt{R}) \times \sqrt{S}$

Dimensions.				Full.			
				$c\sqrt{R}$ (for Velocity).		$A \times c\sqrt{R}$ (for Discharge).	
ft.	in.	ft.	in.	$n = .013$	$n = .015$	$n = .013$	$n = .015$
2	0 ×	3	0	78·3	66·0	349·2	294·4
2	2 ×	3	3	83·0	70·1	434·1	366·6
2	4 ×	3	6	87·6	74·1	531·7	449·8
2	6 ×	3	9	91·8	77·7	639·8	541·6
2	8 ×	4	0	96·2	81·4	762·9	645·5
2	10 ×	4	3	100·2	85·0	896·8	760·7
3	0 ×	4	6	104·4	88·6	1047·1	888·7
3	2 ×	4	9	108·3	92·0	1210·8	1028·6
3	4 ×	5	0	112·2	95·4	1390·2	1182·0
3	6 ×	5	3	116·1	98·8	1585·9	1349·6
3	8 ×	5	6	119·8	102·0	1795·8	1529·0
3	10 ×	5	9	123·5	105·1	2022·9	1721·5
4	0 ×	6	0	127·0	108·2	2265·7	1930·3
4	2 ×	6	3	130 8	111·5	2532·3	2158·6
4	4 ×	6	6	134·2	114·5	2810·1	2397·6
4	6 ×	6	9	137·5	117·5	3104·7	2653·1
4	8 ×	7	0	141·0	120·5	3423·5	2925·7
4	10 ×	7	3	144·4	123·5	3761·6	3217·2
5	0 ×	7	6	147·7	126·5	4116·4	3525·5
5	2 ×	7	9	150·8	129·2	4487·8	3845·0
5	4 ×	8	0	153·9	131·8	4880·2	4179·4
5	6 ×	8	3	157·1	134·7	5299·0	4543·4
5	8 ×	8	6	160·1	137·4	5731·6	4918·9
5	10 ×	8	9	163·3	140·1	6195·6	5315·4
6	0 ×	9	0	166·4	142·9	6679·3	5736·0

Standard Egg-Shape Sewers (*continued*).

Dimensions.				⅔ Full.			
				$c\sqrt{R}$ (for Velocity).		$A \times c\sqrt{R}$ (for Discharge).	
ft.	in.		ft. in.	n='013	n='015	n='013	n='015
2	0	×	3 0	82·9	69·9	239·6	202·0
2	2	×	3 3	87·7	74·2	297·3	251·5
2	4	×	3 6	92·4	78·3	363·1	307·7
2	6	×	3 9	97·0	82·1	437·5	370·3
2	8	×	4 0	101·4	86·1	521·2	442·5
2	10	×	4 3	105·8	89·9	613·6	521·4
3	0	×	4 6	110·0	93·5	715·0	607·7
3	2	×	4 9	114·3	97·2	827·5	703·7
3	4	×	5 0	118·4	100·7	950·7	808·6
3	6	×	5 3	122·4	104·2	1073·2	922·2
3	8	×	5 6	126·4	107·7	1127·3	1045·8
3	10	×	5 9	130·2	111·1	1381·4	1178·8
4	0	×	6 0	134·0	114·4	1549·0	1322·5
4	2	×	6 3	137·6	117·7	1725·5	1476·0
4	4	×	6 6	141·2	120·8	1914·7	1638·0
4	6	×	6 9	144·9	123·9	2119·0	1812·7
4	8	×	7 0	148·5	127·1	2335·9	1999·3
4	10	×	7 3	151·9	130·2	2562·5	2196·5
5	0	×	7 6	155·4	133·2	2806·5	2405·6
5	2	×	7 9	158·8	136·2	3061·7	2625·9
5	4	×	8 0	162·2	139·1	3331·6	2857·1
5	6	×	8 3	165·4	142 0	3614·0	3102·7
5	8	×	8 6	168·7	144·8	3912·1	3357·9
5	10	×	8 9	171·8	147·6	4222·8	3628·0
6	0	×	9 0	175·0	150·5	4550·0	3913·0

Standard Egg-Shape Sewers (*continued*).

Dimensions.				½ Full.			
				$c\sqrt{R}$ (for Velocity).		$A \times c\sqrt{R}$ (for Discharge).	
ft.	in.	ft.	in.	$n = \cdot013$	$n = \cdot015$	$n = \cdot013$	$n = \cdot015$
2	0 ×	3	0	58·9	49·3	60·1	50·3
2	2 ×	3	3	62·4	53·4	74·3	63·5
2	4 ×	3	6	66·1	55·5	91·2	76·6
2	6 ×	3	9	69·4	58·3	110·3	92·7
2	8 ×	4	0	72·8	61·2	131·8	110·8
2	10 ×	4	3	76·1	64·1	155·2	130·8
3	0 ×	4	6	79·1	66·6	181·2	152·5
3	2 ×	4	9	82·3	69·4	209·9	177·0
3	4 ×	5	0	85·4	72·1	241·7	204·0
3	6 ×	5	3	88·3	74·7	274·6	232·3
3	8 ×	5	6	91·2	77·2	311·9	264·0
3	10 ×	5	9	94·1	79·7	351·9	298·1
4	0 ×	6	0	96·9	82·1	394·4	334·1
4	2 ×	6	3	99·9	84·7	440·6	373·5
4	4 ×	6	6	102·5	87·0	488·9	415·0
4	6 ×	6	9	105·3	89·5	542·3	460·9
4	8 ×	7	0	108·0	91·8	598·3	508·6
4	10 ×	7	3	110·5	94·0	656·4	558·4
5	0 ×	7	6	113·2	96·3	719·9	612·5
5	2 ×	7	9	115·7	98·5	785·6	668·8
5	4 ×	8	0	118·4	100·7	856·0	728·1
5	6 ×	8	3	120·9	102·9	929·7	791·3
5	8 ×	8	6	123·3	105·0	1007·4	857·8
5	10 ×	8	9	125·7	107·2	1087·3	927·3
6	0 ×	9	0	128·1	109·2	1172·1	999·2

TABLE XI.

(P. J. Flynn.)

Values of $\sqrt{s}$ for Inclinations of 1 in 4 to 1 in 2000.

s = sine of angle of inclination = fall of water surface in any distance divided by that distance.

Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$
4	·500000	34	·171499	64	·125000
5	·447214	35	·169031	65	·124035
6	·408248	36	·166667	66	·123091
7	·377978	37	·164399	67	·122169
8	·353553	38	·162221	68	·121268
9	·333333	39	·160125	69	·120386
10	·316228	40	·158114	70	·119524
11	·301511	41	·156174	71	·118678
12	·288675	42	·154303	72	·117851
13	·277350	43	·152499	73	·117041
14	·267261	44	·150756	74	·116248
15	·258199	45	·149071	75	·115470
16	·250000	46	·147444	76	·114708
17	·242536	47	·145865	77	·113961
18	·235702	48	·144337	78	·113228
19	·229416	49	·142857	79	·112509
20	·223607	50	·141421	80	·111803
21	·218218	51	·140028	81	·111111
22	·213200	52	·138676	82	·110431
23	·208514	53	·137361	83	·109764
24	·204124	54	·136085	84	·109109
25	·200000	55	·134839	85	·108465
26	·196116	56	·133630	86	·107833
27	·192450	57	·132453	87	·107211
28	·188982	58	·131305	88	·106600
29	·185695	59	·130189	89	·106000
30	·182574	60	·129100	90	·105409
31	·179605	61	·128037	91	·104828
32	·176777	62	·127000	92	·104257
33	·174077	63	·125988	93	·103695

For use in ordinary practice the first four figures after the decimal will suffice.

Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$
94	·103142	134	·086387	174	·075810
95	·102598	135	·086066	175	·075593
96	·102062	136	·085749	176	·075378
97	·101535	137	·085436	177	·075164
98	·101015	138	·085126	178	·074953
99	·100504	139	·084819	179	·074744
100	·100000	140	·084516	180	·074536
101	·099504	141	·084215	181	·074329
102	·099015	142	·083918	182	·074125
103	·098533	143	·083624	183	·073922
104	·098058	144	·083333	184	·073721
105	·097590	145	·083046	185	·073521
106	·097129	146	·082760	186	·073324
107	·096674	147	·082479	187	·073127
108	·096225	148	·082199	188	·072932
109	·095783	149	·081923	189	·072739
110	·095346	150	·081650	190	·072548
111	·094916	151	·081379	191	·072357
112	·094491	152	·081111	192	·072169
113	·094072	153	·080845	193	·071982
114	·093659	154	·080582	194	·071796
115	·093250	155	·080322	195	·071612
116	·092848	156	·080065	196	·071429
117	·092450	157	·079809	197	·071247
118	·092057	158	·079556	198	·071067
119	·091669	159	·079305	199	·070888
120	·091287	160	·079057	200	·070710
121	·090909	161	·078811	201	·070534
122	·090536	162	·078568	202	·070359
123	·090167	163	·078326	203	·070186
124	·089803	164	·078087	204	·070014
125	·089442	165	·077850	205	·069843
126	·089087	166	·077615	206	·069673
127	·088736	167	·077382	207	·069505
128	·088388	168	·077152	208	·069338
129	·088045	169	·076923	209	·069172
130	·087706	170	·076697	210	·069007
131	·087370	171	·076472	211	·068843
132	·087039	172	·076249	212	·068680
133	·086711	173	·076029	213	·068519

Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$
214	·068358	254	·062746	294	·058321
215	·068199	355	·062622	295	·058222
216	·068041	256	·062500	296	·058124
217	·067885	257	·062378	297	·058026
218	·067729	258	·062257	298	·057929
219	·067574	259	·062137	299	·057831
220	·067419	260	·062018	300	·057735
221	·067267	261	·061899	301	·057639
222	·067116	262	·061780	302	·057544
223	·066965	263	·061662	303	·057449
224	·066815	264	·061546	304	·057354
225	·066667	265	·061430	305	·057260
226	·066519	266	·061314	306	·057166
227	·066372	267	·061199	307	·057073
228	·066227	268	·061085	308	·056980
229	·066082	269	·060971	309	·056888
230	·065938	270	·060858	310	·056796
231	·065795	271	·060746	311	·056705
232	·065653	272	·060634	312	·056614
233	·065512	273	·060523	313	·056523
234	·065372	274	·060412	314	·056433
235	·065233	275	·060302	315	·056344
236	·065094	276	·060193	316	·056254
237	·064957	277	·060084	317	·056165
238	·064820	278	·059976	318	·056077
239	·064685	279	·059868	319	·055989
240	·064549	280	·059761	320	·055902
241	·064416	281	·059655	321	·055815
242	·064283	282	·059549	322	·055728
243	·064150	283	·059444	323	·055641
244	·064018	284	·059339	324	·055556
245	·063888	285	·059235	325	·055470
246	·063758	286	·059131	326	·055385
247	·063629	287	·059028	327	·055300
248	·063500	288	·058926	328	·055216
249	·063372	289	·058824	329	·055132
250	·063246	290	·058722	330	·055048
251	·063119	291	·058621	331	·054965
252	·062994	292	·058520	332	·054882
253	·062870	293	·058420	333	·054799

Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$
334	·054717	374	·051709	414	·049147
335	·054636	375	·051640	415	·049088
336	·054555	376	·051571	416	·049029
337	·054474	377	·051502	417	·048970
338	·054393	378	·051434	418	·048911
339	·054312	379	·051366	419	·048853
340	·054232	380	·051299	420	·048795
341	·054153	381	·051231	421	·048737
342	·054074	382	·051164	422	·048679
343	·053995	383	·051097	423	·048621
344	·053916	384	·051031	424	·048564
345	·053838	385	·050965	425	·048507
346	·053760	386	·050899	426	·048450
347	·053683	387	·050833	427	·048393
348	·053606	388	·050767	428	·048337
349	·053529	389	·050702	429	·048280
350	·053452	390	·050637	430	·048224
351	·053376	391	·050572	431	·048168
352	·053300	392	·050507	432	·048113
353	·053224	393	·050443	433	·048057
354	·053149	394	·050379	434	·048001
355	·053074	395	·050315	435	·047946
356	·052999	396	·050252	436	·047891
357	·052925	397	·050188	437	·047836
358	·052851	398	·050125	438	·047782
359	·052778	399	·050062	439	·047728
360	·052705	400	·050000	440	·047673
361	·052632	401	·049938	441	·047619
362	·052559	402	·049876	442	·047565
363	·052486	403	·049814	443	·047511
364	·052414	404	·049752	444	·047458
365	·052342	405	·049690	445	·047404
366	·052270	406	·049629	446	·047351
367	·052199	407	·049568	447	·047298
368	·052129	408	·049507	448	·047245
369	·052060	409	·049447	449	·047193
370	·051988	410	·049387	450	·047140
371	·051917	411	·049326	451	·047088
372	·051847	412	·049266	452	·047036
373	·051778	413	·049207	453	·046984

Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$
454	·046932	494	·044992	534	·043274
455	·046880	495	·044947	535	·043234
456	·046829	496	·044901	536	·043193
457	·046778	497	·044856	537	·043153
458	·046726	498	·044811	538	·043113
459	·046676	499	·044766	539	·043073
460	·046625	500	·044721	540	·043033
461	·046575	501	·044677	541	·042993
462	·046524	502	·044632	542	·042953
463	·046474	503	·044588	543	·042914
464	·046424	504	·044544	544	·042874
465	·046374	505	·044499	545	·042835
466	·046324	506	·044455	546	·042796
467	·046274	507	·044412	547	·042757
468	·046225	508	·044368	548	·042718
469	·046176	509	·044324	549	·042679
470	·046126	510	·044281	550	·042640
471	·046077	511	·044237	551	·042601
472	·046029	512	·044194	552	·042563
473	·045980	513	·044151	553	·042524
474	·045932	514	·044108	554	·042486
475	·045883	515	·044065	555	·042448
476	·045835	516	·044022	556	·042410
477	·045787	517	·043979	557	·042371
478	·045739	518	·043937	558	·042333
479	·045691	519	·043895	559	·042295
480	·045644	520	·043853	560	·042258
481	·045596	521	·043811	561	·042220
482	·045549	522	·043769	562	·042183
483	·045502	523	·043727	563	·042145
484	·045454	524	·043685	564	·042108
485	·045407	525	·043644	565	·042070
486	·045361	526	·043602	566	·042033
487	·045314	527	·043561	567	·041996
488	·045268	528	·043519	568	·041959
489	·045222	529	·043478	569	·041922
490	·045175	530	·043437	570	·041885
491	·045129	531	·043396	571	·041848
492	·045083	532	·043355	572	·041812
493	·045037	533	·044315	573	·041776

Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$
574	·041739	614	·040357	654	·039103
575	·041703	615	·040324	655	·039073
576	·041667	616	·040291	656	·039043
577	·041630	617	·040258	657	·039013
578	·041594	618	·040226	658	·038984
579	·041559	619	·040193	659	·038954
580	·041523	620	·040161	660	·038925
581	·041487	621	·040128	661	·038895
582	·041451	622	·040096	662	·038866
583	·041416	623	·040064	663	·038837
584	·041380	624	·040032	664	·038808
585	·041345	625	·040000	665	·038778
586	·041309	626	·039968	666	·038749
587	·041274	627	·039936	667	·038720
588	·041239	628	·039904	668	·038691
589	·041204	629	·039873	669	·038662
590	·041169	630	·039841	670	·038633
591	·041135	631	·039809	671	·038604
592	·041100	632	·039778	672	·038576
593	·041065	633	·039746	673	·038547
594	·041031	634	·039715	674	·038518
595	·040996	635	·039684	675	·038490
596	·040961	636	·039653	676	·038461
597	·040927	637	·039621	677	·038433
598	·040893	638	·039590	678	·038405
599	·040859	639	·039559	679	·038376
600	·040825	640	·039528	680	·038348
601	·040791	641	·039498	681	·038320
602	·040757	642	·039467	682	·038292
603	·040723	643	·039436	683	·038264
604	·040689	644	·039405	684	·038236
605	·040656	645	·039375	685	·038208
606	·040622	646	·039344	686	·038180
607	·040589	647	·039314	687	·038152
608	·040555	648	·039284	688	·038125
609	·040522	649	·039253	689	·038097
610	·040489	650	·039223	690	·038069
611	·040456	651	·039193	691	·038042
612	·040422	652	·039163	692	·038014
613	·040389	653	·039133	693	·037987

Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$
694	·037959	734	·036911	774	·035944
695	·037932	735	·036885	775	·035921
696	·037905	736	·036860	776	·035898
697	·037878	737	·036835	777	·035875
698	·037851	738	·036810	778	·035852
699	·037824	739	·036786	779	·035829
700	·037796	740	·036761	780	·035806
701	·037769	741	·036736	781	·035783
702	·037743	742	·036711	782	·035760
703	·037716	743	·036686	783	·035737
704	·037689	744	·036662	784	·035714
705	·037662	745	·036637	785	·035691
706	·037636	746	·036613	786	·035669
707	·037609	747	·036588	787	·035646
708	·037582	748	·036563	788	·035623
709	·037556	749	·036539	789	·035601
710	·037529	750	·036515	790	·035578
711	·037503	751	·036490	791	·035556
712	·037477	752	·036466	792	·035533
713	·037450	753	·036442	793	·035511
714	·037424	754	·036418	794	·035489
715	·037398	755	·036394	795	·035466
716	·037372	756	·036370	796	·035444
717	·037346	757	·036346	797	·035422
718	·037320	758	·036322	798	·035399
719	·037294	759	·036298	799	·035377
720	·037268	760	·036274	800	·035355
721	·037242	761	·036250	801	·035333
722	·037216	762	·036226	802	·035311
723	·037190	763	·036202	803	·035289
724	·037164	764	·036179	804	·035267
725	·037139	765	·036155	805	·035245
726	·037113	766	·036131	806	·035223
727	·037088	767	·036108	807	·035201
728	·037063	768	·036084	808	·035179
729	·037037	769	·036061	809	·035158
730	·037012	770	·036038	810	·035136
731	·036986	771	·036014	811	·035115
732	·036961	772	·035991	812	·035093
733	·036936	773	·035967	813	·035071

Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$
814	·035050	854	·034219	894	·033445
815	·035028	855	·034199	895	·033426
816	·035007	856	·034179	896	·033408
817	·034985	857	·034159	897	·033389
818	·034964	858	·034139	898	·033370
819	·034943	859	·034119	899	·033352
820	·034922	860	·034099	900	·033333
821	·034900	861	·034080	901	·033315
822	·034879	862	·034060	902	·033296
823	·034858	863	·034040	903	·033278
824	·034837	864	·034021	904	·033259
825	·034816	865	·034001	905	·033241
826	·034794	866	·033981	906	·033223
827	·034773	867	·033962	907	·033204
828	·034752	868	·033942	908	·033186
829	·034731	869	·033923	909	·033168
830	·034710	870	·033903	910	·033149
831	·034689	871	·033883	911	·033131
832	·034669	872	·033864	912	·033113
833	·034648	873	·033845	913	·033095
834	·034627	874	·033825	914	·033077
835	·034606	875	·033806	915	·033059
836	·034586	876	·033787	916	·033041
837	·034565	877	·033768	917	·033023
838	·034544	878	·033748	918	·033005
839	·034524	879	·033729	919	·032987
840	·034503	880	·033710	920	·032969
841	·034483	881	·033691	921	·032951
842	·034462	882	·033672	922	·032933
843	·034442	883	·033653	923	·032915
844	·034421	884	·033633	924	·032897
845	·034401	885	·033614	925	·032879
846	·034381	886	·033595	926	·032862
847	·034360	887	·033577	927	·032844
848	·034340	888	·033558	928	·032826
849	·034320	889	·033539	929	·032809
850	·034300	890	·033520	930	·032791
851	·034279	891	·033501	931	·032774
852	·034259	892	·033483	932	·032756
853	·034239	893	·033464	933	·032738

Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$
934	·032721	974	·032042	1014	·031404
935	·032703	975	·032026	1015	·031388
936	·032686	976	·032009	1016	·031373
937	·032669	977	·031993	1017	·031357
938	·032651	978	·031977	1018	·031342
939	·032634	979	·031960	1019	·031327
940	·032616	980	·031944	1020	·031311
941	·032599	981	·031928	1021	·031296
942	·032582	982	·031911	1022	·031282
943	·032565	983	·031895	1023	·031265
944	·032547	984	·031879	1024	·031250
945	·032530	985	·031863	1025	·031235
946	·032513	986	·031847	1026	·031219
947	·032496	987	·031830	1027	·031204
948	·032479	988	·031814	1028	·031189
949	·032461	989	·031798	1029	·031174
950	·032444	990	·031782	1030	·031159
951	·032427	991	·031766	1031	·031144
952	·032410	992	·031750	1032	·031129
953	·032393	993	·031734	1033	·031114
954	·032376	994	·031718	1034	·031099
955	·032359	995	·031702	1035	·031083
956	·032342	996	·031686	1036	·031068
957	·032325	997	·031670	1037	·031053
958	·032309	998	·031654	1038	·031038
959	·032292	999	·031639	1039	·031023
960	·032275	1000	·031623	1040	·031009
961	·032258	1001	·031607	1041	·030994
962	·032241	1002	·031591	1042	·030975
963	·032224	1003	·031576	1043	·030964
964	·032208	1004	·031560	1044	·030949
965	·032191	1005	·031544	1045	·030934
966	·032174	1006	·031528	1046	·030919
967	·032158	1007	·031513	1047	·030905
968	·032141	1008	·031497	1048	·030890
969	·032125	1009	·031481	1049	·030875
970	·032108	1010	·031466	1050	·030861
971	·032091	1011	·031450	1051	·030846
972	·032075	1012	·031435	1052	·030831
973	·032059	1013	·031419	1053	·030817

Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$
1054	·030802	1094	·030234	1134	·029696
1055	·030787	1095	·030220	1135	·029683
1056	·030773	1096	·030206	1136	·029669
1057	·030758	1097	·030192	1137	·029656
1058	·030744	1098	·030178	1138	·029643
1059	·030729	1099	·030165	1139	·029630
1060	·030715	1100	·030151	1140	·029617
1061	·030700	1101	·030137	1141	·029604
1062	·030686	1102	·030124	1142	·029591
1063	·030671	1103	·030110	1143	·029578
1064	·030657	1104	·030096	1144	·029566
1065	·030643	1105	·030083	1145	·029553
1066	·030628	1106	·030069	1146	·029540
1067	·030614	1107	·030055	1147	·029527
1068	·030599	1108	·030042	1148	·029514
1069	·030585	1109	·030028	1149	·029501
1070	·030571	1110	·030015	1150	·029488
1071	·030557	1111	·030001	1151	·029476
1072	·030542	1112	·029988	1152	·029463
1073	·030528	1113	·029975	1153	·029450
1074	·030514	1114	·029961	1154	·029438
1075	·030499	1115	·029948	1155	·029425
1076	·030485	1116	·029934	1156	·029412
1077	·030471	1117	·029921	1157	·029399
1078	·030457	1118	·029908	1158	·029386
1079	·030443	1119	·029894	1159	·029374
1080	·030429	1120	·029881	1160	·029363
1081	·030415	1121	·029868	1161	·029348
1082	·030401	1122	·029854	1162	·029336
1083	·030387	1123	·029841	1163	·029323
1084	·030373	1124	·029828	1164	·029311
1085	·030359	1125	·029814	1165	·029298
1086	·030345	1126	·029801	1166	·029285
1087	·030331	1127	·029788	1167	·029273
1088	·030317	1128	·029775	1168	·029264
1089	·030303	1129	·029761	1169	·029248
1090	·030289	1130	·029748	1170	·029235
1091	·030275	1131	·029735	1171	·029223
1092	·030261	1132	·029722	1172	·029210
1093	·030247	1133	·029709	1173	·029198

Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$
1174	·029185	1214	·028701	1254	·028239
1175	·029173	1215	·028689	1255	·028228
1176	·029161	1216	·028677	1256	·028217
1177	·029148	1217	·028665	1257	·028205
1178	·029136	1218	·028653	1258	·028194
1179	·029123	1219	·028641	1259	·028183
1180	·029111	1220	·028630	1260	·028172
1181	·029099	1221	·028617	1261	·028161
1182	·029086	1222	·028506	1262	·028149
1183	·029074	1223	·028595	1263	·028138
1184	·029062	1224	·028583	1264	·028127
1185	·029049	1225	·028571	1265	·028116
1186	·029037	1226	·028559	1266	·028105
1187	·029025	1227	·028548	1267	·028094
1188	·029013	1228	·028536	1268	·028083
1189	·029001	1229	·028525	1269	·028072
1190	·028988	1230	·028513	1270	·028061
1191	·028976	1231	·028501	1271	·028050
1192	·028964	1232	·028490	1272	·028038
1193	·028952	1233	·028478	1273	·028027
1194	·028940	1234	·028467	1274	·028016
1195	·028928	1235	·028455	1275	·028006
1196	·028916	1236	·028444	1276	·027995
1197	·028904	1237	·028433	1277	·027984
1198	·028892	1238	·028421	1278	·027973
1199	·028880	1239	·028409	1279	·027962
1200	·028868	1240	·028398	1280	·027951
1201	·028855	1241	·028387	1281	·027940
1202	·028843	1242	·028375	1282	·027929
1203	·028831	1243	·028364	1283	·027918
1204	·028819	1244	·028352	1284	·027907
1205	·028808	1245	·028341	1285	·027896
1206	·028796	1246	·028329	1286	·027886
1207	·028784	1247	·028318	1287	·027875
1208	·028772	1248	·028307	1288	·027864
1209	·028760	1249	·028295	1289	·027853
1210	·028748	1250	·028284	1290	·027841
1211	·028736	1251	·028273	1291	·027831
1212	·028724	1252	·028262	1292	·027821
1213	·028713	1253	·028250	1293	·027810

REESE LIBRARY OF THE UNIVERSITY

Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$
1294	·027799	1334	·027379	1374	·026978
1295	·027789	1335	·027369	1375	·026968
1296	·027778	1336	·027359	1376	·026958
1297	·027767	1337	·027349	1377	·026948
1298	·027756	1338	·027338	1378	·026939
1299	·027746	1339	·027328	1379	·026929
1300	·027735	1340	·027318	1380	·026919
1301	·027724	1341	·027308	1381	·026909
1302	·027714	1342	·027298	1382	·026899
1303	·027703	1343	·027287	1383	·026890
1304	·027692	1344	·027277	1384	·026880
1305	·027682	1345	·027267	1385	·026870
1306	·027671	1346	·027257	1386	·026861
1307	·027661	1347	·027247	1387	·026851
1308	·027650	1348	·027237	1388	·026841
1309	·027639	1349	·027227	1389	·026832
1310	·027629	1350	·027217	1390	·026822
1311	·027618	1351	·027207	1391	·026812
1312	·027608	1352	·027197	1392	·026803
1313	·027597	1353	·027186	1393	·026793
1314	·027587	1354	·027176	1394	·023784
1315	·027576	1355	·027166	1395	·026774
1316	·027566	1356	·027156	1396	·026764
1317	·027555	1357	·027146	1397	·026755
1318	·027545	1358	·027136	1398	·026745
1319	·027534	1359	·027126	1399	·026736
1320	·027524	1360	·027116	1400	·026726
1321	·027514	1361	·027106	1401	·026717
1322	·027503	1362	·027096	1402	·026707
1323	·027493	1363	·027086	1403	·026698
1324	·027481	1364	·027077	1404	·026688
1325	·027472	1365	·027067	1405	·026679
1326	·027462	1366	·027057	1406	·026669
1327	·027451	1367	·027047	1407	·026659
1328	·027441	1368	·027037	1408	·026650
1329	·027431	1369	·027027	1409	·026641
1330	·027420	1370	·027017	1410	·026631
1331	·027410	1371	·027007	1411	·026622
1332	·027400	1372	·026997	1412	·026612
1333	·027389	1373	·026988	1413	·026603

Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$
1414	·026593	1454	·026225	1494	·025872
1415	·026584	1455	·026216	1495	·025863
1416	·026575	1456	·026207	1496	·025854
1417	·026565	1457	·026198	1497	·025846
1418	·026556	1458	·026189	1498	·025837
1419	·026547	1459	·026180	1499	·025828
1420	·026537	1460	·026171	1500	·025820
1421	·026528	1461	·026162	1501	·025811
1422	·026519	1462	·026153	1502	·025803
1423	·026509	1463	·026144	1503	·025794
1424	·026500	1464	·026135	1504	·025786
1425	·026491	1465	·026126	1505	·025777
1426	·026481	1466	·026118	1506	·025768
1427	·026472	1467	·026109	1507	·025760
1428	·026463	1468	·026100	1508	·025751
1429	·026454	1469	·026091	1509	·025743
1430	·026444	1470	·026082	1510	·025734
1431	·026435	1471	·026073	1511	·025726
1432	·026426	1472	·026064	1512	·025717
1433	·026417	1473	·026055	1513	·025709
1434	·026407	1474	·026047	1514	·025700
1435	·026398	1475	·026038	1515	·025691
1436	·026389	1476	·026029	1516	·025683
1437	·026380	1477	·026020	1517	·025675
1438	·026371	1478	·026011	1518	·025666
1439	·026361	1479	·026003	1519	·025658
1440	·026352	1480	·025994	1520	·025649
1441	·026343	1481	·025985	1521	·025641
1442	·026334	1482	·025976	1522	·025633
1443	·026325	1483	·025967	1523	·025624
1444	·026316	1484	·025959	1524	·025616
1445	·026307	1485	·025950	1525	·025607
1446	·026298	1486	·025941	1526	·025599
1447	·026288	1487	·025933	1527	·025591
1448	·026279	1488	·025924	1528	·025582
1449	·026270	1489	·025915	1529	·025574
1450	·026261	1490	·025907	1530	·025566
1451	·026252	1491	·025898	1531	·025557
1452	·026243	1492	·025889	1532	·025549
1453	·026234	1493	·025880	1533	·025540

Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$
1534	·025532	1574	·025206	1614	·024891
1535	·025524	1575	·025198	1515	·024884
1536	·025516	1576	·025190	1616	·024876
1537	·025507	1577	·025182	1617	·024868
1538	·025499	1578	·025174	1618	·024861
1539	·025491	1579	·025166	1619	·024853
1540	·025482	1580	·025158	1620	·024845
1541	·025474	1581	·025151	1621	·024838
1542	·025466	1582	·025142	1622	·024830
1543	·025457	1583	·025134	1623	·024822
1544	·025449	1584	·025126	1624	·024815
1545	·025441	1585	·025118	1625	·024807
1546	·025433	1586	·025110	1626	·024799
1547	·025425	1587	·025102	1627	·024792
1548	·025416	1588	·025094	1628	·024784
1549	·025408	1589	·025086	1629	·024776
1550	·025400	1590	·025078	1630	·024769
1551	·025392	1591	·025071	1631	·024761
1552	·025384	1592	·025063	1632	·024754
1553	·025375	1593	·025055	1633	·024746
1554	·025367	1694	·025047	1634	·024739
1555	·025359	1595	·025039	1635	·024731
1556	·025351	1596	·025031	1636	·024723
1557	·025343	1597	·025023	1637	·024716
1558	·025335	1598	·025016	1638	·024708
1559	·025327	1599	·025008	1639	·024701
1560	·025318	1600	·025000	1640	·024693
1561	·025310	1601	·024992	1641	·024686
1562	·025302	1602	·024984	1642	·024678
1563	·025294	1603	·024976	1643	·024671
1564	·025286	1604	·024969	1644	·024664
1565	·025278	1605	·024961	1645	·024656
1566	·025270	1606	·024953	1646	·024648
1567	·025262	1607	·024946	1647	·024641
1568	·025254	1608	·024938	1648	·024633
1569	·025246	1609	·024930	1649	·024626
1570	·025238	1610	·024922	1650	·024618
1571	·025230	1611	·024915	1651	·024612
1572	·025222	1612	·024907	1652	·024603
1573	·025214	1613	·024899	1653	·024596

Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$
1654	·024589	1694	·024297	1734	·024015
1655	·024581	1695	·024290	1735	·024008
1656	·024574	1696	·024282	1736	·024001
1657	·024566	1697	·024275	1737	·023994
1658	·024559	1698	·024268	1738	·023987
1659	·024551	1699	·024261	1739	·023980
1660	·024544	1700	·024254	1740	·023973
1661	·024537	1701	·024246	1741	·023966
1662	·024529	1702	·024239	1742	·023959
1663	·024522	1703	·024232	1743	·023953
1664	·024515	1704	·024225	1744	·023946
1665	·024507	1705	·024218	1745	·023939
1666	·024500	1706	·024211	1746	·023932
1667	·024492	1707	·024204	1747	·023925
1668	·024485	1708	·024197	1748	·023918
1669	·024478	1709	·024190	1749	·023911
1670	·024470	1710	·024183	1750	·023905
1671	·024463	1711	·024175	1751	·023898
1672	·024456	1712	·024168	1752	·023891
1673	·024448	1713	·024161	1753	·023884
1674	·024441	1714	·024154	1754	·023878
1675	·024434	1715	·024147	1755	·023871
1676	·024427	1716	·024140	1756	·023864
1677	·024420	1717	·024133	1757	·023857
1678	·024413	1718	·024126	1758	·023850
1679	·024405	1719	·024119	1759	·023843
1680	·024398	1720	·024112	1760	·023837
1681	·024390	1721	·024105	1761	·023830
1682	·024383	1722	·024098	1762	·023823
1683	·024376	1723	·024091	1763	·023816
1684	·024369	1724	·024084	1764	·023809
1685	·024361	1725	·024077	1765	·023803
1686	·024354	1726	·024070	1766	·023796
1687	·024347	1727	·024063	1767	·023789
1688	·024340	1728	·024056	1768	·023783
1689	·024332	1729	·024049	1769	·023776
1690	·024325	1730	·024042	1770	·023769
1691	·024318	1731	·024035	1771	·023762
1692	·024311	1732	·024028	1772	·023756
1693	·024304	1733	·024021	1773	·023749

Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$
1774	·023742	1814	·023479	1854	·023224
1775	·023736	1815	·023473	1855	·023218
1776	·023729	1816	·023466	1856	·023212
1777	·023722	1817	·023460	1857	·023206
1778	·023716	1818	·023453	1858	·023199
1779	·023709	1819	·023447	1859	·023193
1780	·023702	1820	·023440	1860	·023187
1781	·023696	1821	·023434	1861	·023181
1782	·023689	1822	·023427	1862	·023174
1783	·023682	1823	·023421	1863	·023168
1784	·023676	1824	·023415	1864	·023162
1785	·023669	1825	·023408	1865	·023156
1786	·023662	1826	·023402	1866	·023150
1787	·023656	1827	·023395	1867	·023143
1788	·023649	1828	·023389	1868	·023137
1789	·023643	1829	·023383	1869	·023131
1790	·023636	1830	·023376	1870	·023125
1791	·023629	1831	·023370	1871	·023119
1792	·023623	1832	·023363	1872	·023112
1793	·023616	1833	·023357	1873	·023106
1794	·023610	1834	·023351	1874	·023100
1795	·023603	1835	·023344	1875	·023094
1796	·023596	1836	·023338	1876	·023088
1797	·023589	1837	·023331	1877	·023082
1798	·023583	1838	·023325	1878	·023076
1799	·023577	1839	·023319	1879	·023069
1800	·023570	1840	·023313	1880	·023063
1801	·023564	1841	·023306	1881	·023057
1802	·023557	1842	·023300	1882	·023051
1803	·023551	1843	·023294	1883	·023045
1804	·023544	1844	·023287	1884	·023039
1805	·023538	1845	·023281	1885	·023033
1806	·023531	1846	·023275	1886	·023027
1807	·023525	1847	·023268	1887	·023020
1808	·023518	1848	·023262	1888	·023014
1809	·023512	1849	·023256	1889	·023008
1810	·023505	1850	·023250	1890	·023002
1811	·023499	1851	·023243	1891	·022996
1812	·023492	1852	·023237	1892	·022990
1813	·023486	1853	·023230	1893	·022984

Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$	Slope 1 in	$\sqrt{s}$
1894	·022978	1898	·022954	1940	·022704
1895	·022972	1899	·022948	1960	·022588
1896	·022966	1900	·022942	1980	·022473
1897	·022960	1920	·022822	2000	·022361

Table XII.

Quantity of Brickwork for *Circular Sewers.*

2 ft. to 10 ft. diameter.

Diameter.	Circular Sewers. Cubic Yards of Brickwork per Lineal Yard.			
ft. in.	4½ in. Work.	9 in. Work.	13½ in. Work.	18 in. Work.
2 0	·31	·72	—	—
2 1	·32	·74	—	—
2 2	·33	·76	—	—
2 3	·34	·78	—	—
2 4	·35	·80	—	—
2 5	·36	·82	—	—
2 6	·37	·85	—	—
2 7	·39	·88	—	—
2 8	·40	·90	—	—
2 9	·41	·92	—	—
2 10	·42	·94	—	—
2 11	·43	·96	—	—
3 0	·44	·98	—	—
3 1	·45	1·00	—	—
3 2	·46	1·02	—	—
3 3	·47	1·04	—	—
3 4	·48	1·06	—	—
3 5	·49	1·08	—	—
3 6	·51	1·11	—	—
3 7	·52	1·14	—	—
3 8	·53	1·16	—	—
3 9	·54	1·18	—	—
3 10	·55	1·20	—	—
3 11	·56	1·22	—	—
4 0	·57	1·24	2·01	—
4 1	·58	1·26	2·04	—
4 2	·59	1·28	2·07	—
4 3	·60	1·30	2·11	—
4 4	·61	1·33	2·14	—

BRICKWORK FOR CIRCULAR SEWERS *(continued)*.

Diameter.	Circular Sewers. Cubic Yards of Brickwork per Lineal Yard.			
ft. in.	4½ in. Work.	9 in. Work.	13½ in. Work.	18in. Work.
4 5	·63	1·36	2·18	—
4 6	·64	1 38	2·21	—
4 7	·65	1·40	2·25	—
4 8	·66	1·42	2·28	—
4 9	·67	1·44	2·31	—
4 10	·68	1·46	2·34	—
4 11	·69	1·48	2·37	—
5 0	·70	1·50	2·40	—
5 1	·71	1·52	2·43	—
5 2	·72	1·54	2·46	—
5 3	·73	1·56	2·49	—
5 4	·74	1·58	2·52	—
5 5	·75	1·60	2·55	—
5 6	·77	1·63	2·60	—
5 7	·78	1·66	2·64	—
5 8	·79	1·68	2·67	—
5 9	·80	1·70	2·70	—
5 10	·81	1·72	2·73	—
5 11	·82	1·74	2 75	—
6 0	·83	1·77	2·79	3·92
6 1	·84	1·80	2·84	4·00
6 2	·85	1·82	2·88	4·04
6 3	·86	1·84	2·91	4·08
6 4	·88	1·86	2 94	4·12
6 5	·89	1 88	2·97	4·16
6 6	·90	1·90	3·00	4·20
6 7	·91	1·92	3·03	4·24
6 8	·92	1·94	3·06	4·28
6 9	·93	1·96	3·09	4·32
6 10	·94	1·98	3·12	4·36
6 11	·95	2·00	3·15	4·40
7 0	·96	2·02	3·18	4·44
7 1	·97	2·04	3·21	4·48
7 2	·98	2·07	3·25	4·52

Brickwork for Circular Sewers *(continued)*.

Diameter.		Circular Sewers. Cubic Yards of Brickwork per Lineal Yard.			
ft.	in.	4½ in. Work.	9 in. Work.	13½ in. Work.	18in. Work.
7	3	·99	2·10	3·30	4·60
7	4	1·01	2·12	3·33	4·64
7	5	1·02	2·14	3·36	4·68
7	6	1·03	2·16	3·39	4·72
7	7	1·04	2·18	3·42	4·76
7	8	1·05	2·20	3·45	4·80
7	9	1·06	2·22	3·48	4·84
7	10	1·07	2·24	3·51	4·88
7	11	1·08	2·26	3·54	4·92
8	0	1·09	2·28	3·57	4·96
8	1	1·10	2·30	3·60	5·00
8	2	1·11	2·33	3·64	5·04
8	3	1·13	2·36	3·68	5·12
8	4	1·14	2·38	3·72	5·16
8	5	1·15	2·40	3·75	5·20
8	6	1·16	2·42	3·78	5·24
8	7	1·17	2·44	3·81	5·28
8	8	1·18	2·46	2·84	5·32
8	9	1·19	2·48	2·87	5·36
8	10	1·20	2·50	3·90	5·40
8	11	1·21	2·52	3·93	5·44
9	0	1·22	2·55	3 97	5·49
9	1	1·24	2·58	4·02	5·55
9	2	1·25	2·60	4·05	5·60
9	3	1.26	2·62	4·08	5·64
9	4	1·27	2·64	4·11	5·68
9	5	1·28	2·66	4·14	5·72
9	6	1·29	2·68	4·17	5·76
9	7	1·30	2·70	4·20	5·80
9	8	1·31	2·72	4·23	5·84
9	9	1·32	2·74	4·26	5·88
9	10	1·33	2·76	4·29	5·92
9	11	1·34	2·79	4 33	5·96
10	0	1·36	2·81	4·37	6·02

Table XIII.

Quantity of Brickwork for *Standard Egg-Shape* and *New Egg-Shape* Sewers.

2 ft. × 3 ft. to 6 ft. × 9 ft. diameter.

Note.—The quantity of brickwork for a new egg-shape sewer is from 1 to 2 per cent. less than that of a standard egg-shape sewer of equal internal dimensions, and for all practical purposes may therefore be taken as equal to same.

Dimensions.				Standard Egg-Shape. Cubic Yards of Brickwork per Lineal Yard.		
ft.	in.	ft.	in.	4½ in. Work.	9 in. Work.	13½ in. Work.
2	0 ×	3	0	·38	·86	1·44
2	2 ×	3	3	·41	·91	1·52
2	4 ×	3	6	·43	·97	1·60
2	6 ×	3	9	·46	1·02	1·68
2	8 ×	4	0	·49	1·08	1·77
2	10 ×	4	3	·52	1·13	1·85
3	0 ×	4	6	·54	1·19	1·93
3	2 ×	4	9	·57	1·24	2·01
3	4 ×	5	0	·60	1·30	2·10
3	6 ×	5	3	·63	1·35	2·18
3	8 ×	5	6	·65	1·41	2·26
3	10 ×	5	9	·68	1·46	2·34
4	0 ×	6	0	·71	1·52	2·42
4	2 ×	6	3	·74	1·57	2·51
4	4 ×	6	6	·77	1·63	2·60
4	6 ×	6	9	·79	1·68	2·67
4	8 ×	7	0	·82	1·74	2·75
4	10 ×	7	3	·85	1·79	2·84
5	0 ×	7	6	·88	1·85	2·92
5	2 ×	7	9	·90	1·90	3·00
5	4 ×	8	0	·93	1·96	3·08
5	6 ×	8	3	·96	2·01	3·17
5	8 ×	8	6	·99	2·07	3·25
5	10 ×	8	9	1·01	2·12	3·33
6	0 ×	9	0	1·04	2·18	3·51

TABLE XIV.

Cubic Yards of *Excavation per Lineal Yard* of Trenches, 2 ft. to 15 ft. wide and 4 ft. to 20 ft. deep.

Average Depth.	WIDTH.									
	2′ 0″	2′ 1″	2′ 2″	2′ 3″	2′ 4″	2′ 5″	2′ 6″	2′ 7″	2′ 8″	2′ 9″
4 0	·888	·926	·963	1·000	1·037	1·074	1·111	1·148	1·185	1·222
4 1	·908	·945	·983	1·021	1·058	1·096	1·134	1·172	1·210	1·248
4 2	·927	·964	1·003	1·042	1·079	1·118	1·157	1·196	1·235	1·274
4 3	·946	·983	1·023	1·063	1·100	1·140	1·180	1·220	1·260	1·300
4 4	·965	1·002	1·043	1·084	1·121	1·162	1·203	1·244	1·285	1·326
4 5	·984	1·021	1·063	1·105	1·142	1·184	1·226	1·268	1·310	1·352
4 6	1·000	1·040	1·083	1·126	1·163	1·206	1·250	1·292	1·335	1·378
4 7	1·019	1·069	1·103	1·147	1·184	1·228	1·273	1·316	1·360	1·404
4 8	1·038	1·088	1·123	1·168	1·205	1·250	1·296	1·340	1·385	1·430
4 9	1·057	1·107	1·143	1·189	1·226	1·272	1·319	1·364	1·410	1·456
4 10	1·076	1·126	1·163	1·210	1·247	1·294	1·342	1·388	1·435	1·482
4 11	1·095	1·145	1·183	1·231	1·268	1·316	1·365	1·412	1·460	1·507
5 0	1·111	1·164	1·203	1·250	1·289	1·343	1·388	1·435	1·481	1·528
5 1	1·130	1·183	1·223	1·271	1·310	1·365	1·411	1·459	1·506	1·554
5 2	1·149	1·202	1·243	1·292	1·331	1·387	1·434	1·483	1·531	1·580
5 3	1·168	1·221	1·263	1·313	1·352	1·409	1·457	1·507	1·556	1·606
5 4	1·187	1·240	1·283	1·334	1·373	1·431	1·480	1·531	1·581	1·632
5 5	1·206	1·259	1·303	1·355	1·394	1·453	1·503	1·555	1·606	1·658
5 6	1·225	1·278	1·323	1·376	1·415	1·475	1·526	1·579	1·631	1·684
5 7	1·244	1·297	1·343	1·397	1·436	1·497	1·549	1·603	1·656	1·710
5 8	1·263	1·316	1·363	1·418	1·457	1·519	1·572	1·627	1·681	1·736
5 9	1·282	1·335	1·383	1·439	1·478	1·541	1·595	1·651	1·706	1·762
5 10	1·301	1·354	1·403	1·460	1·499	1·563	1·618	1·675	1·731	1·788
5 11	1·320	1·373	1·423	1·481	1·520	1·585	1·641	1·699	1·756	1·812
6 0	1·333	1·392	1·443	1·500	1·541	1·611	1·664	1·722	1·777	1·833
6 1	1·352	1·411	1·463	1·521	1·562	1·633	1·687	1·746	1·802	1·859
6 2	1·371	1·430	1·483	1·542	1·583	1·655	1·710	1·770	1·827	1·885
6 3	1·390	1·449	1·503	1·563	1·604	1·677	1·733	1·794	1·852	1·911
6 4	1·409	1·468	1·523	1·584	1·625	1·699	1·766	1·818	1·877	1·937
6 5	1·428	1·487	1·543	1·605	1·646	1·721	1·789	1·832	1·902	1·963

Excavation in Trenches *(continued)*.

Average Depth.		Width.									
		2′ 0″	2′ 1″	2′ 2″	2′ 3″	2′ 4″	2′ 5″	2′ 6″	2′ 7″	2′ 8″	2′ 9″
6	6	1·447	1·506	1·563	1·626	1·667	1·743	1·812	1·856	1·927	1·989
6	7	1·466	1·525	1·583	1·647	1·688	1·765	1·835	1·880	1·952	2·015
6	8	1·485	1·544	1·603	1·668	1·709	1·787	1·858	1·904	1·977	2·041
6	9	1·504	1·563	1·623	1·689	1·730	1·809	1·881	1·928	2·002	2·067
6	10	1·523	1·582	1·643	1·710	1·751	1·831	1·904	1·952	2·027	2 093
6	11	1·542	1·601	1·663	1·731	1·772	1·853	1·927	1·976	2·052	2·119
7	0	1·555	1·620	1·685	1·750	1·811	1·879	1·944	2·009	2·070	2·139
7	1	1·574	1·639	1·705	1·771	1·833	1·901	1·967	2·033	2·095	2·165
7	2	1·593	1·658	1·725	1·792	1·851	1·923	1·990	2·057	2·120	2·191
7	3	1·612	1·677	1·745	1·813	1·875	1·945	2·013	2·081	2·145	2·217
7	4	1·631	1·696	1·765	1·834	1·896	1·967	2·036	2·105	2·170	2·243
7	5	1·650	1·715	1·785	1·855	1·917	1·989	2·059	2·129	2·195	2·269
7	6	1·669	1·734	1·805	1·876	1·938	2·011	2·082	2·153	2·220	2·295
7	7	1·688	1·753	1·825	1·897	1·959	2·033	2·105	2·177	2·245	2·321
7	8	1·707	1·772	1·845	1·918	1·980	2·055	2·128	2·201	2·270	2·347
7	9	1·726	1·791	1·865	1·939	2·001	2·077	2·151	2·225	2·295	2·373
7	10	1·745	1·810	1·885	1·960	2·022	2·099	2·174	2·249	2·320	2·399
7	11	1·764	1·829	1·905	1·981	2·043	2·121	2·197	2·273	2·345	2·425
8	0	1·777	1·851	1·926	2·000	2·071	2·148	2·222	2·296	2·364	2·444

Excavation in Trenches *(continued)*.

Average Depth.	Width. 2′ 10″	2′ 11″	3′ 0″	3′ 3″	3′ 6″	3′ 9″	4′ 0″	4′ 3″	4′ 6″	4′ 9″
4 0	1·259	1·296	1·333	1·444	1·555	1·666	1·777	1·888	2·000	2·111
4 1	1·285	1·323	1·361	1·474	1·587	1·701	1·814	1·927	2·042	2·155
4 2	1·311	1·350	1·389	1·504	1·619	1·736	1·851	1·966	2·084	2·199
4 3	1·337	1·377	1·417	1·534	1·651	1·771	1·888	2·005	2·126	2·243
4 4	1·363	1·404	1·445	1·564	1·683	1·806	1·925	2·044	2·168	2·287
4 5	1·389	1·431	1·473	1·594	1·715	1·841	1·962	2·083	2·210	2·331
4 6	1·415	1·458	1·500	1·624	1·750	1·876	2·000	2·122	2·252	2·375
4 7	1·441	1·485	1·528	1·654	1·782	1·911	2·037	2·161	2·294	2·419
4 8	1·467	1·512	1·556	1·684	1·814	1·946	2·074	2·200	2·336	2·463
4 9	1·493	1·539	1·584	1·714	1·846	1·981	2·111	2·239	2·378	2·507
4 10	1·519	1·566	1·612	1·744	1·878	2·016	2·148	2·278	2·420	2·551
4 11	1·545	1·593	1·640	1·774	1·910	2·051	2·185	2·317	2·462	2·595
5 0	1·574	1·621	1·666	1·806	1·944	2·083	2·222	2·361	2·500	2·639
5 1	1·600	1·648	1·694	1·836	2·976	2·118	2·259	2·400	2·542	2·683
5 2	1·626	1·675	1·722	1·866	2·008	2·153	2·296	2·439	2·584	2·727
5 3	1·652	1·702	1·750	1·896	2·040	2·188	2·333	2·478	2·626	2·771
5 4	1·678	1·729	1·778	1·926	2·072	2·223	2·370	2·517	2·668	2·815
5 5	1·704	1·756	1·806	1·956	2·104	2·258	2·407	2·556	2·710	2·859
5 6	1·730	1·783	1·834	1·986	2·136	2·293	2·444	2·595	2·752	2·903
5 7	1·756	1·810	1·862	2·016	2·168	2·328	2·481	2·634	2·794	2·947
5 8	1·782	1·837	1·890	2·046	2·200	2·363	2·518	2·673	2·836	2·991
5 9	1·808	1·864	1·918	2·076	2·232	2·398	2·555	2·712	2·878	3·035
5 10	1·834	1·891	1·946	2·106	2·264	2·433	2·592	2·751	2·920	3·079
5 11	1·860	1·918	1·974	2·136	2·296	2·468	2·629	2·790	2·962	3·123
6 0	1·889	1·944	2·000	2·167	2·333	2·500	2·666	2·833	3·000	3·167
6 1	1·915	1·971	2·028	2·197	2·365	2·535	2·703	2·872	3·042	3·211
6 2	1·941	1·998	2·056	2·227	2·397	2·570	2·740	2·911	3·084	3·255
6 3	1·967	2·025	2·084	2·257	2·429	2·605	2·777	2·950	3·126	3·299
6 4	1 993	2·052	2·112	2·287	2·461	2·640	2·814	2·989	3·168	3·343
6 5	2·019	2·079	2·140	2·317	2·493	2·675	2·851	3·028	3·210	3·387
6 6	2·045	2·106	2·168	2·347	2·525	2·710	2·888	3·067	3·252	3·431
6 7	2·071	2·133	2·196	2·377	2·557	2·745	2·925	3·106	3·294	3·485
6 8	2·097	2·160	2·224	2·407	2·589	2·780	2·962	3·145	3·336	3·529
6 9	2·123	2·187	2·252	2·437	2·621	2·815	2·999	3·184	3·278	3·573

Excavation in Trenches *(continued)*.

Average Depth.	Width.									
	2′ 10″	2′ 11″	3′ 0″	3′ 3″	3′ 6″	3′ 9″	4′ 0″	4′ 3″	4′ 6″	4′ 9″
6 10	2·149	2·214	2·280	2·467	2·653	2·850	3·036	3·223	3·420	3·617
6 11	2·175	2·241	2·308	2·497	2 685	2 885	3·073	3·262	3·462	3·661
7 0	2·203	2·268	2·333	2·522	2·722	2·917	3·111	3·305	3·500	3·694
7 1	2·229	2·295	2·361	2·552	2·754	2·952	3·148	3·344	3·542	3·738
7 2	2·255	2·322	2·389	2·582	2·786	2·987	3·185	3·383	3·584	3·782
7 3	2·281	2·347	2·417	2·612	2·818	3·022	3·222	3·422	3·626	3·826
7 4	2·307	2·376	2·445	2·642	2·850	3·057	3·259	3·461	3·668	3·870
7 5	2·333	2·403	2·473	2·672	2·882	3·092	3·296	3·500	3·710	3·914
7 6	2·359	2·430	2·501	2·702	2·914	3·127	3·333	3·539	3·752	3·958
7 7	2·385	2·457	2·529	2·732	2·946	3·162	3·370	3·578	3·794	4·002
7 8	2·411	2·484	2·557	2·762	2·978	3·196	3·407	3·617	3·836	4·046
7 9	2·437	2·511	2·585	2·792	3·010	3·232	3·444	3·656	3·878	4·090
7 10	2·463	2·538	2·613	2·822	3·042	3·267	3·481	3·695	3·920	4·134
7 11	2·489	2·565	2·641	2·852	3·074	3·302	3·518	3·734	3·962	4·178
8 0	2·518	2·592	2·666	2·888	3·111	3·333	3·555	3·777	4·000	4·222

Excavation in Trenches *(continued)*.

Average Depth.	Width.									
	5′ 0″	5′ 3″	5′ 6″	5′ 9″	6′ 0″	6′ 3″	6′ 6″	6′ 9″	7′ 0″	7′ 3″
4 0	2·222	2·333	2·444	2·555	2·666	2·777	2·888	3·000	3·111	3·222
4 1	2·268	2·382	2·495	2·608	2·722	2·835	2·948	3·063	3·176	3·289
4 2	2·314	2·431	2·546	2·661	2·778	2·893	3·008	3·126	3·241	3·356
4 3	2·360	2·480	2·597	2·714	2·834	2·951	3·068	3·189	3·306	3·423
4 4	2·406	2·529	2·648	2·767	2·890	3·009	3·128	3·252	3·371	3·490
4 5	2·452	2·578	2·699	2·820	2·946	3·067	3·188	3·315	3·436	3·557
4 6	2·498	2·627	2·750	2·873	3·000	3·125	3·248	3·378	3·501	3·624
4 7	2·544	2·676	2·801	2·926	3·056	3·183	3·308	3·441	3·566	3·691
4 8	2·590	2·725	2·852	2·979	3·112	3·241	3·368	3·504	3·631	3·758
4 9	2·636	2·774	2·903	3·032	3·168	3·299	3·428	3·567	3·696	3·825
4 10	2·682	2·823	2·954	3·085	3·224	3·357	3·488	3·630	3·761	3·892
4 11	2·728	2·872	3·005	3·138	3·280	3·415	3·548	3·693	3·826	3·959
5 0	2·778	2·917	3·056	3·195	3·334	3·473	3·612	3·751	3·890	4·029
5 1	2·824	2·966	3·107	3·248	3·390	3·531	3·672	3·814	3·955	4·096
5 2	2·870	3·015	3·158	3·301	3·446	3·589	3·732	3·877	4·020	4·163
5 3	2·916	3·064	3·209	3·354	3·502	3·647	3·792	3·940	4·085	4·230
5 4	2·962	3·113	3·260	3·407	3·558	3·705	3·852	4·003	4·150	4·297
5 5	3·008	3·162	3·311	3·460	3·614	3·763	3·912	4·066	4·215	4·364
5 6	3·054	3·211	3·362	3·513	3·670	3·821	3·972	4·129	4·280	4·431
5 7	3·100	3·260	3·413	3·566	3·726	3·879	4·032	4·192	4·345	4·498
5 8	3·146	3·309	3·464	3·619	3·782	3·937	4·092	4·255	4·410	4·565
5 9	3·192	3·358	3·515	3·672	3·838	3·995	4·152	4·318	4·475	4·632
5 10	3·238	3·407	3·566	3·725	3·894	4·053	4·212	4·381	4·540	4·699
5 11	3·284	3·456	3·617	3·778	3·949	4·111	4·272	4·444	4·605	4·766
6 0	3·334	3·500	3·667	3·834	4·000	4·167	4·334	4·500	4·667	4·834
6 1	3·380	3·549	3·718	3·887	4·056	4·225	4·394	4·563	4·732	4·901
6 2	3·426	3·598	3·769	3·940	4·112	4·283	4·454	4·626	4·797	4·968
6 3	3·472	3·647	3·820	3·993	4·168	4·341	4·514	4·689	4·862	5·035
6 4	3·518	3·696	3·871	4·046	4·224	4·399	4·574	4·752	4·927	5·102
6 5	3·564	3·745	3·922	4·099	4·280	4·457	4·634	4·815	4·992	5·169
6 6	3·610	3·794	3·973	4·152	4·334	4·515	4·694	4·878	5·055	5·236
6 7	3·656	3·843	4·024	4·205	4·390	4·573	4·754	4·941	5·122	5·303
6 8	3·702	3·892	4·075	4·258	4·446	4·631	4·814	5·004	5·187	5·370
6 9	3·748	3·941	4·126	4·311	4·503	4·689	4·874	5·067	5·252	5·437

Excavation in Trenches *(continued)*.

Average Depth.	Width.									
	6′ 0″	5′ 3″	5′ 6″	5′ 9″	6′ 0″	6′ 3″	6′ 6″	6 9″	7′ 0″	7′ 3″
6 10	3·794	3·990	4·177	4·364	4·558	4·747	4·934	5·130	5·317	5·504
6 11	3·840	4·039	4·228	4·417	4·614	4·805	4·994	5·193	5·382	5·571
7 0	3·888	4·082	4·276	4·470	4·666	4·860	5·054	5·248	5·444	5·638
7 1	3·934	4·131	4·327	4·523	4·722	4·918	5·114	5·311	5·509	5·705
7 2	3·980	4·180	4·378	4·576	4·778	4·976	5·174	5·374	5·574	5·772
7 3	4·026	4·229	4·429	4·629	4·834	5·034	5·234	5·437	5·639	5·839
7 4	4·072	4·278	4·480	4·682	4·890	5·092	5·294	5·500	5·704	5·906
7 5	4·118	4·327	4·531	4·735	4·946	5·150	5·354	5·563	5·769	5·973
7 6	4·164	4·376	4·582	4·788	5·002	5·208	5·414	5·626	5·834	6·040
7 7	4·210	4·425	4·633	4·841	5·058	5·266	5·474	5·689	5·899	6·107
7 8	4·256	4·474	4·684	4·894	5·114	5·324	5·534	5·752	5·964	6·174
7 9	4·302	4·523	4·735	4·947	5·170	5·382	5·594	5·815	6·029	6·241
7 10	4·348	4·572	4·786	5·000	5·226	5·440	5·654	5·878	6·094	6·308
7 11	4·399	4·621	4·837	5·054	5·282	5·498	5·714	5·941	6·159	6·375
8 0	4·444	4·666	4·888	5·111	5·333	5·555	5·777	6·000	6·222	6·444

Excavation in Trenches *(continued)*.

Average Depth.	Width. 7′ 6″	7′ 9″	8′ 0″	8′ 3″	8′ 6″	8′ 9″	9′ 0″	9′ 6″	10′ 0″	10′ 6″
4 0	3·333	3·444	3·555	3·666	3·777	3·888	4·000	4·222	4·444	4·666
4 1	3·403	3·516	3·629	3·742	3·856	3·969	4·083	4·310	4·537	4·763
4 2	3·473	3·588	3·703	3·818	3·935	3·050	4·166	4·398	4·630	4·860
4 3	3·543	3·660	3·777	3·894	4·014	4·131	4·249	4·486	4·723	4·957
4 4	3·613	3·732	3·851	3·970	4·093	4·212	4·332	4·574	4·816	5·054
4 5	3·683	3·804	3·925	4·046	4·172	4·293	4·415	4·662	4·909	5·151
4 6	3·753	3·876	3·999	4·122	4·251	4·374	4·498	4·750	5·002	5·248
4 7	3·823	3·948	4·073	4·198	4·330	4·455	4·581	4·838	5·095	5·345
4 8	3·893	4·020	4·147	4·274	4·409	4·536	4·664	4·926	5·188	5·442
4 9	3·963	4·092	4·221	4·350	4·488	4·617	4·747	5·014	5·281	5·539
4 10	4·033	4·164	4·295	4·426	4·567	4·698	4·830	5·102	5·374	5·636
4 11	4·103	4·236	4·369	4·502	4·646	4·779	4·913	5·190	5·467	5·733
5 0	4·168	4·305	4·444	4·583	4·722	4·861	5·000	5·278	5·556	5·834
5 1	4·236	4·377	4·518	4·659	4·801	4·942	5·083	5·366	5·649	5·931
5 2	4·306	4·449	4·592	4·735	4·880	5·023	5·166	5·454	5·742	6·028
5 3	4·376	4·521	4·666	4·811	4·959	5·104	5·249	5·542	5·835	6·125
5 4	4·446	4·593	4·740	4·888	4·938	5·185	5·332	5·630	5·928	6·222
5 5	4·516	4·665	4·814	4·964	5·117	5·266	5·415	5·718	6·021	6·319
5 6	4·586	4·737	4·888	5·040	5·196	5·347	5·498	5·806	6·114	6·416
5 7	4·656	4·809	5·962	5·116	5·275	5·428	5·581	5·894	6·207	6·513
5 8	4·726	4·881	5·036	5·192	5·354	5·509	5·664	5·982	6·300	6·610
5 9	4·796	4·953	5·110	5·268	5·433	5·590	5·747	6·070	6·393	6·707
5 10	4·866	5·025	5·184	5·344	5·512	5·671	5·830	6·158	6·486	6·804
5 11	4·936	5·097	5·258	5·420	5·591	5·752	5·913	6·246	6·579	6·901
6 0	5·000	5·167	5·334	5·500	5·667	5·834	6·000	6·334	6·667	7·000
6 1	5·070	5·239	5·408	5·576	5·746	5·915	6·083	6·422	6·760	7·097
6 2	5·140	5·311	5·482	5·652	5·825	5·996	6·166	6·510	6·853	7·194
6 3	5·210	5·383	5·556	5·728	5·904	6·077	6·249	6·598	6·946	7·291
6 4	5·280	5·455	5·630	5·804	5·983	6·158	6·332	6·586	7·039	7·388
6 5	5·350	5·527	5·704	5·880	6·062	6·239	6·415	6·774	7·132	7·485
6 6	5·420	5·599	5·778	5·956	6·141	6·320	6·498	6·862	7·225	7·582
6 7	5·490	5·671	5·852	6·032	6·220	6·401	6·581	6·940	7·318	7·679
6 8	5·560	5·743	5·926	6·106	6·299	6·482	6·664	7·028	7·411	7·776
6 9	5·630	5·815	6·000	6·184	6·378	6·563	6·747	7·116	7·504	7·873

Exc vation in Trenches *(continued)*.

Width.

Average Depth.	7′ 6″	7′ 9″	8′ 0″	8′ 3″	8′ 6″	8′ 9″	9′ 0″	9′ 6″	10′ 0″	10′ 6″
6 10	5·700	5·887	6·074	6·260	6·457	6·644	6·830	7·204	7·597	7·970
6 11	5·770	5·959	6·148	6·336	6·536	6·725	6·917	7·292	7·690	8·067
7 0	5·832	6·026	6·222	6·416	6·610	6·804	7·000	7·388	7·777	8·166
7 1	5·902	6·098	6·296	6·492	6·689	6·885	7·083	7·476	7·870	8·263
7 2	5·972	6·170	6·370	6·568	6·768	6·966	7·166	7·564	7·963	8·360
7 3	6·042	6·242	6·444	6·644	6·847	7·047	7·249	7·652	8·056	8·457
7 4	6·112	6·314	6·518	6·720	6·926	7·128	7·332	7·740	8·149	8·554
7 5	6·182	6·386	6·592	6·796	7·005	7·209	7·415	7·828	8·242	8·651
7 6	6·252	6·458	6·666	6·872	7·084	7·290	7·498	7·916	8·335	8·748
7 7	6·322	6·530	6·740	6·948	7·163	7·371	7·581	8·004	8·428	8·845
7 8	6·392	6·602	6·814	7·024	7·242	7·452	7·664	8·092	8·520	8·942
7 9	6·462	6·674	6·888	7·100	7·321	7·533	7·747	8·180	8·612	9·039
7 10	6·532	6·746	6·962	7·176	7·400	7·614	7·830	8·268	8·704	9·138
7 11	6·595	6·816	7·036	7·257	7·479	7·695	7·913	8·356	8·797	9·235
8 0	6·666	6·888	7·111	7·333	7·555	7·777	8·000	8·444	8·888	9·333

Excavation in Trenches *(continued)*.

Average Depth.		Width.								
		11′ 0″	11′ 6″	12′ 0″	12′ 6″	13′ 0″	13′ 6″	14′ 0″	14′ 6″	15′ 0″
4	0	4·888	5·111	5·333	5 555	5·777	6·000	6·222	6·444	6·666
4	1	4·990	5·218	5·444	5·671	5·897	6·125	6·352	6·578	6·805
4	2	5·092	5·325	5·555	5·787	6·017	6·250	6·482	6·712	6·944
4	3	5·194	5·432	5·666	5·903	6·137	6·375	6·612	6·846	7·083
4	4	5·296	5·539	5·777	6·019	6·257	6 500	6·742	6·980	7·222
4	5	5·398	5·646	5·888	6·135	6·377	6 625	6·872	7·114	7·361
4	6	5·500	5·753	5·999	6·251	6 497	6·750	7·000	7·248	7·500
4	7	5·602	5·860	6·110	6·367	6·617	6·875	7·130	7·382	7·639
4	8	5·704	5·967	6·221	6·483	6·737	7·000	7·260	7·516	7·778
4	9	5·806	6·074	6·332	6 599	6·857	7·125	7·390	7·650	7 917
4	10	5·908	6·181	6·443	6·715	6·977	7·250	7·520	7·784	8·056
4	11	6·010	6·288	6·554	6·831	7·097	7·375	7·650	7·918	8·195
5	0	6·112	6·390	6·668	6·946	7·224	7·500	7·778	8·056	8·334
5	1	6·214	6·497	6·779	7·062	7·344	7·625	7·908	8·190	8·473
5	2	6·316	6·604	6 890	7·178	7·464	7·750	8·038	8·324	8·612
5	3	6·418	6·711	7·001	7·294	7·584	7·875	8·168	8·458	8·751
5	4	6·520	6·818	7·112	7·410	7·704	8·000	8·298	8·592	8·890
5	5	6·622	6·925	7·223	7·526	7·824	8·125	8·428	8·726	9·029
5	6	6·724	7·032	7·334	7·642	7 944	8·250	8·558	8·860	9·168
5	7	6·826	7·139	7·445	7·758	8·064	8·375	8·688	8·994	9·307
5	8	6·928	7·246	7·556	7·874	8·184	8·500	8·818	9·128	9·446
5	9	7·030	7·353	7·667	7·990	8·304	8·625	8·948	9·262	9·585
5	10	7·132	7·460	7·778	8·106	8·424	8·750	9·078	9·396	9·724
5	11	7·233	7·566	7·889	8·222	8·544	8·875	9·208	9·530	9·863
6	0	7·334	7·667	8·000	8·334	8·667	9·000	9·334	9·667	10·000
6	1	7·436	7·774	8·111	8·450	8·787	9·125	9·464	9·801	10·139
6	2	7·538	7·881	8·222	8·566	8·907	9·250	9·594	9·935	10·278
6	3	7·640	7·988	8·333	8·682	9·027	9·375	9·724	10·069	10·417
6	4	7·742	8·095	8·444	8·798	9·147	9·500	9·854	10·203	10·556
6	5	7·844	8·202	8·555	8·914	9·267	9·625	9·984	10·337	10·695
6	6	7·946	8·309	8·666	9·030	9·387	9·750	10·114	10·471	10·834
6	7	8·048	8·416	8·777	9·146	9·507	9·875	10·244	10·605	10·973
6	8	8·150	8·523	8·888	9·262	9·627	10·000	10·373	10·739	11·112
6	9	8·252	8·630	8·999	9·378	9·747	10·125	10·502	10·873	11·251

Excavation in Trenches *(continued)*.

Width.

Average Depth.	11′ 0″	11′ 6″	12′ 0″	12′ 6″	13′ 0″	13′ 6″	14′ 0″	14′ 6″	15′ 0″
6 10	8·354	8·737	9·111	9·494	9·867	10·250	10·631	11·007	11·390
6 11	8·456	8·841	9·222	9·610	9·987	10·375	10·760	11·141	11·529
7 0	8·555	8·944	9·333	9·722	10·111	10·500	10·889	11·278	11·667
7 1	8·657	9·051	9·444	9·838	10·231	10·625	11·019	11·412	11·806
7 2	8·759	9·158	9·555	9·954	10·351	10·750	11·149	11·546	11·945
7 3	8·861	9·265	9·666	10·070	10·471	10·875	11·279	11·680	12·084
7 4	8·963	9·372	9·777	10·186	10·591	11·000	11·409	11·814	12·223
7 5	9·065	9·479	9·888	10·302	10·711	11·125	11·539	11·948	12·362
7 6	9·167	9·586	10·000	10·318	10·831	11·250	11·669	12·082	12·501
7 7	9·269	9·693	10·111	10·434	10·951	11·375	11·799	12·216	12·640
7 8	9·370	9·798	10·222	10·550	11·071	11·500	11·929	12·350	12·779
7 9	9·472	9·905	10·333	10·666	11·191	11·625	12·059	12·484	12·918
7 10	9·573	10·011	10·444	10·782	11·311	11·750	12·189	12·618	13·057
7 11	9·675	10·118	10·555	10·898	11·431	11·875	12·319	12·752	13·196
8 0	9·777	10·222	10·666	11·111	11·555	12·000	12·444	12·888	13·333

M^2

EXCAVATION IN TRENCHES *(continued)*.

Average Depth.		WIDTH.								
		2′ 0″	2′ 3″	2′ 6″	2′ 9″	3′ 0″	3′ 3″	3′ 6″	3′ 9″	4′ 0″
8	0	1·777	2·000	2·222	2·444	2·666	2·888	3·111	3·333	3·555
8	3	1·833	2·062	2·291	2·520	2·749	2·978	3·208	3·437	3·666
8	6	1·889	2·124	2·360	2·596	2·832	3·068	3·305	3·541	3·777
8	9	1·945	2·186	2·429	2·672	2·915	3·158	3·402	3·645	3·888
9	0	2·000	2·250	2·500	2·750	3·000	3·250	3·500	3·750	4·000
9	3	2·056	2·312	2·569	2·826	3·083	3·340	3·597	3·854	4·111
9	6	2·112	2·374	2·638	2·902	3·166	3·430	3·694	3·958	4·222
9	9	2·168	2·436	2·707	2·978	3·249	3·520	3·791	4·062	4·333
10	0	2·222	2·500	2·777	3·055	3·333	3·611	3·888	4·166	4·444
10	3	2·278	2·562	2·846	3·131	3·416	3·701	3·985	4·270	4·555
10	6	2·334	2·624	2·915	3·207	3·499	3·791	4·082	4·374	4·666
10	9	2·390	2·686	2·984	3·283	3·582	3·881	4·179	4·478	4·777
11	0	2·444	2·750	3·055	3·361	3·666	3·972	4·277	4·583	4·888
11	3	2·500	2·812	3·124	3·437	3·749	4·062	4·374	4·687	5·000
11	6	2·556	2·874	3·193	3·513	3·833	4·152	4·471	4·791	5·111
11	9	2·612	2·937	3·263	3·589	3·916	4·243	4·568	4·895	5·222
12	0	2·666	3·000	3·333	3·666	4·000	4·333	4·666	5·000	5·333
12	6	2·777	3·125	3·472	3·819	4·166	4·513	4·860	5·208	5·555
13	0	2·888	3·250	3·611	3·972	4·333	4·693	5·055	5·417	5·777
13	6	3·000	3·375	3·750	4·125	4·500	4·873	5·250	5·625	6·000
14	0	3·111	3·500	3·888	4·278	4·666	5·055	5·444	5·833	6·222
14	6	3·222	3·625	4·027	4·431	4·833	5·235	5·638	6·041	6·444
15	0	3·333	3·750	4·166	4·583	5·000	5·415	5·833	6·250	6·666
15	6	3·444	3·875	4·305	4·736	5·166	5·595	6·027	6·458	6·888
16	0	3·555	4·000	4·444	4·888	5·333	5·777	6·222	6·666	7·111
16	6	3·666	4·125	4·583	5·041	5·500	5·957	6·416	6·874	7·333
17	0	3·777	4·250	4·722	5·194	5·666	6·137	6·610	7·082	7·555
17	6	3·888	4·375	4·861	5·347	5·833	6·317	6·805	7·290	7·777
18	0	4·000	4·500	5·000	5·500	6·000	6·500	7·000	7·500	8·000
18	6	4·111	4·625	5·139	5·653	6·166	6·680	7·194	7·708	8·222
19	0	4·222	4·750	5·278	5·806	6·333	6·860	7·388	7·916	8·444
19	6	4·333	4·875	5·417	5·959	6·500	7·040	7·582	8·124	8·666
20	0	4·444	5·000	5·555	6·111	6·666	7·222	7·777	8·333	8·888

Excavation in Trenches *(continued)*.

Average Depth.		Width.							
		4′ 3″	4′ 6″	4′ 9″	5′ 0″	5′ 3″	5′ 6″	5′ 9″	6′ 0″
8	0	3·777	4·000	4·222	4·444	4·666	4·888	5·111	5·333
8	3	3·895	4·125	4·354	4·583	4·812	5·041	5·271	5·500
8	6	4·013	4·250	4·486	4·722	4·958	5·194	5·431	5·667
8	9	4·131	4·375	4·618	4·861	5·104	5·347	5·591	5·834
9	0	4·250	4·500	4·750	5·000	5·250	5·500	5·750	6·000
9	3	4·368	4·625	4·882	5·139	5·396	5·653	5·910	6·167
9	6	4·489	4·750	5·014	5·278	5·542	5·806	6·070	6·334
9	9	4·607	4·875	5·146	5·417	5·688	5·959	6·230	6·501
10	0	4·722	5·000	5·277	5·555	5·833	6·111	6·388	6·666
10	3	4·840	5·125	5·409	5·694	5·979	6·264	6·548	6·833
10	6	4·958	5·250	5·541	5·833	6·125	6·417	6·708	7·000
10	9	5·076	5·375	5·674	5·972	6·271	6·570	6·868	7·167
11	0	5·193	5·500	5·805	6·111	6·416	6·722	7·027	7·333
11	3	5·311	5·625	5·937	6·250	6·561	6·875	7·187	7·500
11	6	5·429	5·750	6·069	6·389	6·708	7·028	7·347	7·667
11	9	5·547	5·875	6·201	6·528	6·854	7·181	7·507	7·834
12	0	5·666	6·000	6·333	6·666	7·000	7·333	7·666	8·000
12	6	5·902	6·250	6·597	6·944	7·292	7·639	7·986	8·333
13	0	6·139	6·500	6·861	7·222	7·583	7·944	8·305	8·666
13	6	6·375	6·750	7·125	7·500	7·875	8·250	8·625	9·000
14	0	6·611	7·000	7·389	7·777	8·166	8·555	8·945	9·333
14	6	6·847	7·250	7·653	8·055	8·458	8·861	9·265	9·666
15	0	7·083	7·500	7·917	8·333	8·750	9·166	9·585	10·000
15	6	7·319	7·750	8·181	8·611	9·042	9·472	9·903	10·333
16	0	7·555	8·000	8·444	8·888	9·333	9·777	10·222	10·666
16	6	7·791	8·250	8·708	9·166	9·625	10·083	10·542	11·000
17	0	8·027	8·500	8·972	9·444	9·917	10·388	10·862	11·333
17	6	8·263	8·750	9·236	9·722	10·209	10·694	11·181	11·666
18	0	8·500	9·000	9·500	10·000	10·500	11·000	11·500	12·000
18	6	8·736	9·250	9·764	10·278	10·792	11·306	11·820	12·333
19	0	8·972	9·500	10·028	10·555	11·084	11·612	12·139	12·666
19	6	9·208	9·750	10·292	10·833	11·375	11·918	12·458	13·000
20	0	9·444	10·000	10·555	11·111	11·666	12·222	12·777	13·333

Excavation in Trenches *(continued)*.

Average Depth.		Width.							
		6′ 3″	6′ 6″	6′ 9″	7′ 0″	7′ 3″	7′ 6″	7′ 9″	8′ 0″
8	0	5·555	5·777	6·000	6·222	6·444	6·666	6·888	7·111
8	3	5·729	5·958	6·188	6·417	6·646	6·875	7·104	7·333
8	6	5·803	6·139	6·376	6·612	6·848	7·084	7·320	7·555
8	9	5·977	6·320	6·564	6·807	7·049	7·292	7·536	7·777
9	0	6·250	6·500	6·750	7·000	7·250	7·500	7·750	8·000
9	3	6·424	6·681	6·938	7·195	7·452	7·709	7·966	8·222
9	6	6·598	6·862	7·126	7·390	7·654	7·918	8·182	8·444
9	9	6·772	7·043	7·314	7·585	7·856	8·127	8·398	8·666
10	0	6·944	7·222	7·500	7·777	8·055	8·333	8·611	8·888
10	3	7·118	7·403	7·688	7·972	8·257	8·542	8·827	9·111
10	6	7·292	7·584	7·876	8·167	8·459	8·751	9·043	9·333
10	9	7·466	7·765	8·064	8·362	8·660	8·960	9·259	9·555
11	0	7·639	7·944	8·250	8·555	8·861	9·166	9·472	9·777
11	3	7·815	8·125	8·434	8·750	9·063	9·375	9·688	10·000
11	6	7·989	8·306	8·626	8·945	9·265	9·584	9·904	10·222
11	9	8·162	8·487	8·814	9·140	9·465	9·793	10·120	10·444
12	0	8·333	8·666	9·000	9·333	9·666	10·000	10·333	10·666
12	6	8·680	9·027	9·375	9·722	10·169	10·417	10·764	11·111
13	0	9·027	9·388	9·750	10·111	10·472	10·833	11·195	11·555
13	6	9·375	9·750	10·125	10·500	10·875	11·250	11·625	12·000
14	0	9·722	10·111	10·500	10·889	11·278	11·666	12·055	12·444
14	6	10·069	10·472	10·875	11·278	11·681	12·083	12·486	12·888
15	0	10·416	10·833	11·250	11·666	12·083	12·500	12·917	13·333
15	6	10·763	11·194	11·625	12·055	12·486	12·917	13·347	13·777
16	0	11·111	11·555	12·000	12·444	12·888	13·333	13·777	14·222
16	6	11·457	11·916	12·375	12·833	13·291	13·750	14·208	14·666
17	0	11·804	12·277	12·750	13·222	13·694	14·166	14·639	15·111
17	6	12·152	12·638	13·125	13·611	14·097	14·583	15·070	15·555
18	0	12·500	13·000	13·500	14·000	14·500	15·000	15·500	16·000
18	6	12·847	13·361	13·875	14·389	14·903	15·417	15·931	16·444
19	0	13·194	13·722	14·250	14·777	15·306	15·833	16·361	16·888
19	6	13·541	14·083	14·625	15·166	15·709	16·250	16·792	17·333
20	0	13·888	14·444	15·000	15·555	16·111	16·666	17·222	17·777

Excavation in Trenches *(continued)*.

Average Depth.	Width.							
	8′ 3″	8′ 6″	8′ 9″	9′ 0″	9′ 6″	10′ 0″	10′ 6″	11′ 0″
8 0	7·333	7·555	7·777	8·000	8·444	8·888	9·333	9·777
8 3	7·562	7·791	8·020	8·250	8·708	9·166	9·625	10·083
8 6	7·791	8·027	8·263	8·500	8·972	9·444	9·917	10·389
8 9	8·019	8·263	8·506	8·750	9·236	9·722	10·209	10·695
9 0	8·250	8·500	8·750	9·000	9·500	10·000	10·500	11·000
9 3	8·479	8·736	8·993	9·250	9·764	10·278	10·792	11·306
9 6	8·708	8·972	9·236	9·500	10·028	10·556	11·084	11·612
9 9	8·937	9·208	9·479	9·750	10·292	10·834	11·375	11·918
10 0	9·166	9·444	9·732	10·000	10·555	11·111	11·666	12·222
10 3	9·395	9·680	9·965	10·250	10·819	11·389	11·958	12·528
10 6	9·624	9·916	10·208	10·500	11·083	11·667	12·250	12·834
10 9	9·852	10·152	10·451	10·750	11·347	11·945	12·542	13·140
11 0	10 083	10·388	10·694	11·000	11·611	12·222	12·833	13·444
11 3	10·312	10·624	10·937	11·250	11·875	12·500	13·125	13·750
11 6	10·541	10·860	11·180	11·500	12·139	12·778	13·417	14·056
11 9	10·770	11·096	11·423	11·750	12·403	13·056	13·709	14·361
12 0	11·000	11·333	11·666	12·000	12·666	13·333	14·000	14·666
12 6	11·458	11·805	12·152	12·500	13·194	13·888	14·583	15·277
13 0	11·916	12·277	12·638	13·000	13·722	14·444	15·167	15·888
13 6	12·375	12·750	13·125	13·500	14·250	15·000	15·750	16·500
14 0	12·833	13·222	13·611	14·000	14·777	15·555	16·333	17·111
14 6	13·291	13·694	14·097	14·500	15·305	16·111	16·916	17·722
15 0	13·750	14·166	14·583	15·000	15·833	16·666	17·500	18·333
15 6	14·208	14·638	15·069	15·500	16·361	17·222	18·083	18·944
16 0	14·666	15·111	15·555	16·000	16·888	17·777	18·666	19·555
16 6	15·125	15·583	16·041	16·500	17·416	18·333	19·250	20·111
17 0	15 583	16·055	16·527	17·000	17·944	18·888	19·833	20·722
17 6	16·041	16·527	17·013	17·500	18·472	19·444	20·416	21·333
18 0	16·500	17·000	17·500	18 000	19·000	20·000	21·000	22·000
18 6	16·958	17·472	17·986	18·500	19·528	20·555	21·583	22·611
19 0	17·416	17·944	18·472	19·000	20·056	21·111	22·167	23·222
19 6	17·875	18·416	18·958	19·500	20·584	21·666	22·750	23·833
20 0	18·333	18·888	19·444	20·000	21·111	22·222	23·333	24·444

EXCAVATION IN TRENCHES *(continued)*.

WIDTH.

Average Depth.		11′ 6″	12′ 0″	12′ 6″	13′ 0″	13′ 6″	14′ 0″	14′ 6″	15′ 0″
8	0	10·222	10·066	11·111	11·555	12·000	12·444	12·888	13·333
8	3	10·542	11·000	11·485	11·916	12·375	12·833	13·291	13·750
8	6	10·862	11·333	11·805	12·277	12·750	13·222	13·694	14·167
8	9	11·182	11·666	12·152	12·638	13·125	13·611	14·097	14·584
9	0	11·500	12·000	12·500	13·000	13·500	14·000	14·500	15·000
9	3	11·820	12·333	12·847	13·361	13·875	14·389	14·903	15·417
9	6	12·140	12·666	13·194	13·722	14·250	14·778	15·306	15·834
9	9	12·460	13·000	13·541	14·083	14·625	15·167	15·709	16·251
10	0	12·777	13·333	13·888	14·444	15·000	15·555	16·111	16·666
10	3	13·097	13·666	14·235	14·805	15·375	15·944	16·514	17·083
10	6	13·417	14·000	14·582	15·166	15·750	16·333	16·917	17·500
10	9	13·737	14·333	14·929	15·527	16·125	16·722	17·320	17·917
11	0	14·055	14·666	15·277	15·888	16·500	17·111	17·722	18·333
11	3	14·375	15·000	15·624	16·249	16·875	17·500	18·125	18·750
11	6	14·695	15·333	15·971	16·610	17·250	17·889	18·528	19·167
11	9	15·014	15·666	16·318	16·971	17·625	18·278	18·931	19·584
12	0	15·333	16·000	16·666	17·333	18·000	18·666	19 333	20·000
12	6	15·972	16·666	17·361	18 055	18·750	19·444	20·139	20·833
13	0	16·611	17·333	18·056	18·777	19·500	20·222	20·945	21·666
13	6	17·250	18·000	18·750	19·500	20·250	21·000	21·750	22·500
14	0	17·888	18·666	19·444	20·222	21·000	21·777	22·555	23·333
14	6	18·527	19·333	20·139	20·944	21·750	22·555	23·361	24·166
15	0	19·166	20·000	20·834	21·666	22·500	23·333	24·166	25·000
15	6	19·805	20·666	21·529	22·388	23·250	24·111	24·972	25·833
16	0	20·444	21·333	22·222	23·111	24·000	24·888	25·777	26·666
16	6	21·083	22·000	22·917	23·833	24·750	25·666	26·583	27·500
17	0	21·722	22·666	23·611	24·555	25·500	26·444	27·389	28·333
17	6	22·361	23·333	24·306	25·277	26·250	27·222	28·195	29·166
18	0	23·000	24·000	25·000	26·000	27·000	28·000	29·000	30·000
18	6	23·639	24·666	25·695	26·722	27·750	28·777	29·806	30·833
19	0	24·278	25·333	26·390	27·444	28·500	29·555	30·611	31·666
19	6	24·917	26·000	27·083	28·166	29·250	30·333	31·417	32·500
20	0	25·555	26·666	27·777	28·888	30·000	31·111	32·222	33·333

Table XV.

Gallons per *Minute* Sewage Flow due to Population.

Population.	Average Flow during Twenty-Four Hours.				Maximum Flow (Half in Six Hours).			
	At per Head.				At per Head.			
	20 Glls.	25 Glls.	30 Glls.	40 Glls.	20 Glls.	25 Glls.	30 Glls.	40 Glls.
	Glls. per Minute.	Glls. per Minute.	Glls. per Minute.	Glls. per Minute.	Glls. per Minute.	Glls. per Minute.	Glls. per Minute.	Glls. per Minute.
500	7	8·5	10	14	14	17	21	28
1000	14	17	21	28	28	35	42	56
2000	28	35	42	56	56	70	83	112
3000	42	52	62	84	84	104	125	166
4000	56	70	83	111	111	139	167	222
5000	69	86	104	139	139	174	208	278
6000	83	104	125	166	166	209	250	334
7000	97	121	146	194	194	242	292	388
8000	111	139	167	222	222	278	338	444
9000	125	156	187	250	250	313	375	500
10000	139	174	207	278	278	347	417	556
20000	278	347	417	556	556	694	833	1110
30000	416	520	625	833	833	1041	1250	1666
40000	555	694	833	1110	1110	1388	1667	2220
50000	694	867	1042	1390	1390	1736	2083	2778
60000	833	1041	1250	1666	1666	2082	2500	3332
70000	972	1215	1458	1944	1944	2428	2916	3888
80000	1110	1388	1667	2220	2220	2775	3334	4440
90000	1250	1562	1875	2500	2500	3122	3750	5000
100000	1390	1736	2083	2778	2778	3473	4166	5556

Table XVI.

Cubic Feet per *Second* Sewage Flow due to Population.

Population.	Average Flow during Twenty-Four Hours.				Maximum Flow (Half in Six Hours).			
	At per Head.				At per Head.			
	20 Glls.	25 Glls.	30 Glls.	40 Glls.	20 Glls.	25 Glls.	30 Glls.	40 Glls.
	Cubic ft. per sec.	Cubic ft. per sec.	Cubic ft. per sec.	Cubic ft. per sec.	Cubic ft. per sec.	Cubic ft. per sec.	Cubic ft. per sec.	Cubic ft. per sec.
500	.018	·023	·027	·037	·037	·045	·056	·074
1000	.037	·045	·056	·074	·074	·093	·111	·148
2000	·074	·093	·111	·148	·148	·139	·222	·296
3000	·111	·139	·167	·222	·222	·278	·333	·444
4000	·148	·185	·222	·296	·296	·370	·444	·592
5000	·185	·231	·277	·370	·370	·462	·555	·740
6000	·222	·278	·333	·444	·444	·555	·666	·888
7000	·259	·324	·388	·518	·518	·647	·777	1·036
8000	·296	·370	·444	·592	·592	·740	·888	1·184
9000	·333	·416	·500	·666	·666	·833	1·000	1·332
10000	·370	·462	·555	·740	·740	·925	1·110	1·480
20000	·740	·925	1·110	1·480	1·480	1·850	2·220	2·960
30000	1·110	1·388	1·665	2·220	2·220	2·780	3·330	4·440
40000	1·480	1·850	2·200	2·960	2·960	3·700	4·440	5·920
50000	1·850	2·310	2·770	3·700	3·700	4 620	5·550	7·400
60000	2·220	2·780	3·330	4·440	4·440	5·550	6·660	8·880
70000	2·590	3·240	3·880	5·180	5·180	6·470	7·770	10·360
80000	2·960	3·700	4·440	5·920	5 920	7·400	8 880	11 840
90000	3·330	4·160	5·000	6·660	6·660	8 330	10 000	13·320
100000	3·700	4·620	5·550	7·400	7·400	9·250	11·100	14·800

Table XVII.

Cubic Feet of *Rainfall* on Drainage Areas.

Total Volume.

Acres.	Depth of Rainfall in Inches.					
	$\frac{1}{10}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	1	2
	Cubic Feet.	Cubic Feet.	Cubic Feet.	Cubic Feet.	Cubic Feet.	Cubic Feet.
1	363	454	908	1815	3630	7260
2	726	908	1815	3630	7260	14520
3	1089	1362	2723	5445	10890	21780
4	1452	1816	3630	7260	14520	29040
5	1815	2270	4540	9075	18150	36300
6	2178	2724	5445	10890	21780	43560
7	2541	3178	6353	12705	25410	50820
8	2904	3632	7260	14520	29040	58080
9	3267	4086	8168	16335	32670	65340
10	3630	4540	9080	18150	36300	72600

Note.—The range of this table may be extended by simply moving the decimal, and also by addition, thus: Required total volume of $\frac{1}{4}$ in. of rainfall on 673 acres—

600	acres	= 5445	× 100	=	544500
70	,,	= 6353	× 10	=	63530
3	,,	= 2723		=	2723
673	acres with $\frac{1}{4}$-in. rainfall			=	610753 cubic ft.

Table XVIII.

Cubic Feet per *Second* of *Rain Water* corresponding to Rate of Rainfall per Hour.

Acres.	Rate of Rainfall (Inches per Hour).					
	$\frac{1}{10}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	1	2
	Cubic Feet per Second.	Cubic Feet per Second.	Cubic Feet per Second.	Cubic Feet per Second.	Cubic Feet per Second.	Cubic Feet per Second.
1	·10	·125	·25	·50	1	2
2	·20	·25	·50	1·00	2	4
3	·30	·375	·75	1·50	3	6
4	·40	·50	1·00	2·00	4	8
5	·50	·625	1·25	2·50	5	10
6	·60	·75	1·50	3·00	6	12
7	·70	·875	1·75	3·50	7	14
8	·80	1·00	2·00	4·00	8	16
9	·90	1·125	2·25	4·50	9	18
10	1·00	1·25	2·50	5·00	10	20

Note.—It is usual in general calculations to assume that only half the rainfall will run off within the hour. In that case the figures in the table must be divided by 2. The range of the table may be extended in the manner explained under previous table (xvii.).

TABLE XIX.

(T. HIGHAM.)

(Supplemental to Table II., Part 3, page 44).

Values of Kutter's coefficient "C" for different values of $\sqrt{R}$ and n ($s = \cdot001$ *constant*).

$\sqrt{R}$	$n = \cdot010$		$n = \cdot011$		$n = \cdot012$	
	C	Diff. ·01	C	Diff. ·01	C	Diff. ·01
·2	70·0	2·09	60·7	1·88	53·3	1·70
·3	90·9	1·59	79·5	1·46	70·3	1·34
·4	106·9	1·26	94·1	1·16	83·7	1·08
·5	119·5	1·01	105·8	·95	94·6	·89
·6	129·6	·84	115·2	·79	103·4	·75
·7	138·0	·70	123·1	·67	110·9	·63
·8	145·0	·60	129·8	·57	117·2	·55
·9	151·0	·52	135·5	·49	122·7	·47
1·0	156·2	·45	140 4	·43	127·4	·42
·1	160·6	·39	144·8	·38	131·6	·37
·2	164·6	·35	148·6	·34	135·3	·33
·3	168·1	·31	151·9	·30	138·5	·29
·4	171·2	·28	155·0	·27	141·5	·26
·5	174·0	·25	157·7	·25	144·1	·24
·6	176·5	·23	160·2	·22	146·5	·22
·7	178·8	·21	162·4	·20	148·7	·20
·8	180·9	·19	164·4	·19	150·7	·18
·9	182·8	·17	166·3	·17	152·5	·17
2·0	184·5	·16	168·0	·16	154·2	·16
·1	186·1	·15	169·6	·15	155·8	·14
·2	187·6	·14	171·1	·14	157·2	·13
·3	189·0	·13	172·4	·13	158·6	·13

TABLE XIX. (*continued*).

$\sqrt{R}$	n=·013		n=·015		n=·017	
	C	Diff. ·01	C	Diff. ·01	C	Diff. ·01
·2	47·3	1·56	38·1	1·31	31·6	1·13
·3	62·8	1·24	51·3	1·07	42·9	·94
·4	75·2	1·01	62·0	·89	52·3	·79
·5	85·3	·83	70 8	·74	60·1	·67
·6	93·6	·71	78·3	·64	66·8	·58
·7	100·7	·60	84·6	·55	72·6	·50
·8	106·7	·52	90·1	·48	77·7	·44
·9	111·9	·45	94·9	·42	82·1	·39
1·0	116·5	·40	99·1	·37	86·0	·35
·1	120·5	·36	102·9	·33	89·5	·31
·2	124·0	·32	106·2	·30	92·6	·28
·3	127·2	·29	109 2	·27	95·5	·26
·4	130·1	·26	111·9	·25	98·1	·24
·5	132·7	·23	114·4	·22	100·4	·21
·6	135·0	·21	116·6	·21	102·5	·20
·7	137·1	·20	118·6	·19	104·5	·18
·8	139·1	·18	120·5	·18	106·3	·17
·9	140·9	·17	122·3	·16	108·0	·16
2·0	142·6	·15	123·9	·15	109·6	·15
·1	144·1	·14	125·4	·14	111·0	·13
·2	145 5	·13	126·8	·13	112·4	·13
·3	146·9	·12	128·0	·12	113·6	·12

EXAMPLE: Required "C" when $\sqrt{R}$=·433 and n=·013

By Table when $\sqrt{R}$=·4 C = 75·2
" " =·03 " = 3 × Diff. 1·01 = 3·03
" " =·033 " = 3 × ·101 = ·303

When $\sqrt{R}$=·433 and n=·013, then C =78·533

USEFUL MEMORANDA.

Law of Discharge.

The gradients being equal, the discharge of sewers varies as the square root of the fifth power of the diameter ($\sqrt{d^5}$). The diameters remaining equal, the velocity and discharge will vary as the square root of the sine of the angle of inclination ($\sqrt{s}$).

Conversion Table.

	Per Second.	Per Minute.	Per Hour.	Per 24 Hours.
Cubic feet	1	60	3,600	86,400
Gallons	6¼ (6·235)	375	22,500	540,000

To convert cubic feet per minute and cubic feet per second into gallons per twenty-four hours:—

Cubic feet per min. × 9,000 = gallons per twenty-four hours.
Cubic feet per sec. × 540,000 = gallons per twenty-four hours.

Minimum Inclination Formula.

The following empirical formula will give the approximate minimum inclination for a sewer of a clear diameter of d inches, and either circular or egg-shaped:—

$$\text{Minimum inclination per cent.} = \frac{100}{5d + 50}$$

Eytelwein's Formula.

Eytelwein's formula, hitherto most extensively used by English sewerage engineers, gives too high velocities for small sewers and too low velocities for large sewers.

Approximate Maximum Rate of Rainfall.

It is by no means improbable that some definite relation exists between the mean annual rainfall and the maximum rate of fall during storms. Captain Hoxie's empirical formula, based on observations in the United States, is

$$r = \frac{R}{12}$$

Where R = mean annual rainfall in inches.
r = probable maximum rainfall for one hour, in inches.

Time will show whether this formula can be safely applied to English meteorological conditions, and, if so, whether 12, the denominator in the fraction, gives the best approach to accuracy.

Approximate Variation of Flow of Sewage.

Let F = maximum flow about noon,
f = minimum flow about 3 o'clock in the morning,
Q = total quantity discharged per twenty-four hours in dry weather,

then F = ·0017 Q,
f = ·00027 Q.

Increase of Population.

Let v = rate of increase per inhabitant,
n = number of years,
P_n = population after n years,
P_1 = population in first year,

$$\text{then } 1+v = \sqrt[n-1]{\frac{P_n}{P_1}} = \frac{\log. P_n - \log. P_1}{n-1}$$

$$\text{and } P_n = P_1 \times (1+v)^{n-1}$$

It is usual in designing sewerage schemes to provide at the start for an increase of 25 to 33 per cent. of the existing population. Local conditions however, have a most important influence on the rapidity of increase, and each case must be carefully considered.

Comparative Quantity of Brickwork.

A standard egg-shape sewer requires about 5 per cent. more brickwork than a circular sewer of equal sectional area.

Kutter's Coefficient of Friction (n).

Kutter has conclusively demonstrated the important influence which the condition of the wetted perimeter has on the discharge. This influence may be compared to the action of incrustated ships' hulls in retarding the speed. Hence the importance of selecting, wherever possible, materials of high glaze, with as few joints as practicable.

The choice of a numerical value of n is a matter of judgment and experience. For instance, whilst experiments on new glazed stoneware pipe sewers,

truly and accurately laid, give ·010 or ·011 as the value of n, it must be remembered that few, if any, sewers as laid in actual practice can remain true and perfect for any considerable length of time. Surfaces become incrustated, subsidences take place, joints are dislocated and solids deposited on the inverts. In that case n would become ·013, or even ·015, instead of ·011, which assumes a good condition.

The following table gives the average values of n under various conditions:—

TABLE OF AVERAGE VALUES OF n.

Material of Sewer.	Condition of Surface.			
	Perfect.	Good.	Fair.	Bad.
	$n=$	$n=$	$n=$	$n=$
Glazed stoneware pipe ...	·010	·011	·013	·015
Brickwork, ordinary	·012	·013	·015	·017
Brickwork, glazed	·011	·012	·013	014
Rendering, cement mortar	011	·012	·013	·015
Rendering, neat cement ...	·010	·011	·012	013
Ashlar, dressed	·013	·014	·015	·017
Iron (cast), uncoated... ...	·012	·013	·014	·015
Iron (wrought) and steel ...	·011	·012	·013	·014

NOTE.—For general calculations ·013 is usually taken for glazed pipes and ·015 for ordinary brick sewers. This will allow an ample margin for deterioration, and has been found to agree closely with gaugings of sewers in actual practice and which had been in use for some time. For new pipe and brick sewers ·011 and ·013 respectively should be used.

REESE LIBRARY OF THE UNIVERSITY

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

Reader's Memoranda.

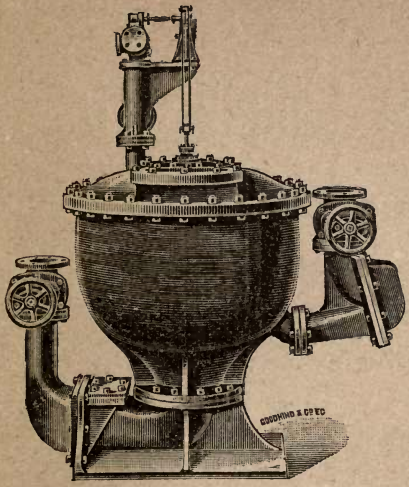
SHONE

PNEUMATIC EJECTORS.

FOR RAISING

SEWAGE, SLUDGE, PAIL CONTENTS, WATER, &c.

AUTOMATIC, EFFECTIVE, ECONOMICAL.



✳

As used at
RANGOON,
KARACHI,
BOMBAY,
EASTBOURNE,
SOUTHAMPTON,
NORWICH,
IPSWICH,
ARAD (Hungary),
ETC.,
and many other
Towns.

✳

AIR COMPRESSING MACHINERY,

&c.

For pamphlets and full particulars, apply to the Manufacturers—

HUGHES & LANCASTER,

47 Victoria Street, London, S.W.,

ENGLAND.

Contractors for Drainage and Water Supply Works.

THE SURVEYOR

— AND —

MUNICIPAL AND COUNTY ENGINEER.

Weekly, 3d. ***Yearly, 15s. (post free).***

For Members of Local Authorities, Contractors, Consulting Engineers, and Municipal and County Engineers.

NOTE.—Copies of this paper may be purchased by Local Authorities to assist them in the discharge of their duties, and charged to local funds.

THE COUNTY COUNCIL TIMES

— AND —

District and Parish Councils Advertiser.

Weekly, 3d. ***Yearly, 12s. (post free).***

The Only Organ of the County Councils.

NOTE.—Copies of this paper may be purchased by Local Authorities to assist them in the discharge of their duties, and charged to local funds.

THE

MUNICIPAL OFFICER.

— THE —

Official Journal of the Municipal Officers' Association.

Monthly, 6d. ***Yearly, 5s. (post free).***

Free to Members of the Association.

Editorial Offices—

St. Bride's House, 24 Bride Lane, Fleet Street, E.C.

Publishing Offices—

13 New Street, Hill, Fleet Street, E.C.

To the New Borough and District Councils.

JAMES WOODWARD, Ltd.

(Established 1790),

Contractors to Her Majesty's Government,

MANUFACTURERS OF

BEST STONEWARE PIPES AND FITTINGS,

Including the following well-known Joints:—

EWING'S PATENT XENTRIC SHOULDER (Archer Patent).

WOODWARD'S DOUBLE SEAL (Stanford Joint).

SOLE MANUFACTURERS OF

FREEMAN'S PATENT MANHOLE CHANNELS.

Street Gullies, Intercepting Traps, &c.
Chimney Tops, Kitchen Sinks, Garden Tiles and Vases.
Finest Glazed Bricks.
Fire Bricks and Clay, Boiler Blocks, &c.

Postal Address :

SWADLINCOTE, near Burton-on-Trent.

National Telephone: No. 3. Telegraphic Address: "WOODWARD, SWADLINCOTE."

* *

St. Bride's Press Publications.

"Clearly printed, concisely written, and convenient in size."

3. **Dilapidations.** By SIDNEY PERKS, P.A.S.I., A.R.I.B.A. Price 6d., post free.
7. **Betterment.** By ALFRED THOMAS MACER, P.A.S.I. Price 1s., post free.
10. **Drainage Works and Sanitary Fittings.** By WILLIAM H. MAXWELL, ASSOC.M.INST.C.E., Borough Engineer and Surveyor, Tunbridge Wells. Second Edition. Price 1s., post free.
11. **Table of Discharge from Circular Sewers when Running Full, in Cubic Feet per Minute.** By a Municipal Engineer. Second Edition. Price 1s., post free.
12. **Housing of the Labouring Classes.** By H. PERCY BOULNOIS, M.I.C.E. Price 1s., post free.
13. **The Sewerage Engineer's Note-Book,** being Standard Notes on Sewer Formulæ and Sewerage Calculations. By ALBERT WOLLHEIM, A.M.I.C.E. Price 3s. 6d., post free. *Second edition.*
14. **Flow of Sewage.** By JOHN P. DALTON, Engineer and Surveyor, Ryton-on-Tyne. Price 6d., post free.
15. **Metrical Tables for Engineers, Surveyors, Chemists, Merchants, &c.** By FREDERIC ELIE GAY, Assistant City Surveyor, Bath. Price 2s., post free.
16. **Party Structures. London Building Act, 1894, Part VIII.** By SYDNEY PERKS, A.R.I.B.A., P.A.S.I. Price 1s., post free.
17. **House Drainage: Its Inspection and Testing, &c.** By R. J. JENKINS, M.S.A., P.A.S.I., &c. Price 1s., post free.
18. **Testing of Portland Cement for Smaller Municipal Works.** By H. H. HUMPHREYS, A.M.I.C.E. Price 1s., post free.
19. **Description of Various Sewage Disposal Works.** A Report prepared by R. O. WYNNE ROBERTS, A.M.I.C.E., City Engineer, Cape Town, formerly Borough Surveyor and Engineer, Oswestry. Price 1s., post free.
20. **Examinations in Sanitary Science. Questions, with Suggestive Answers.** By ERNEST R. MATTHEWS, Author of "Stresses and Strains on Iron Beams and Girders." Price 6d., post free.

21. **A Hand-Book of Highway Cases noted in "The Surveyor and Municipal and County Engineer,"** comprising cases relating to Accidents on Highways; Encroachment and Obstruction; Extraordinary Traffic; Maintenance, Repair and Improvement of Roads, Streets and Bridges; The Rights, Duties and Liabilities of Highway Authorities; Private Street Works and the Laying Out of New Streets. Carefully revised and corrected by J. B. REIGNIER CONDER, Law Editor of "THE SURVEYOR AND MUNICIPAL AND COUNTY ENGINEER." Price 2s. 6d., post free.

22. **Diagrams Exhibiting the Discharges and Velocities of Circular and Oval Sewers and Water Conduits, together with Notes on the Design of Sewerage Schemes.** By EDWIN B. NEWTON, F.S.I., A.M.I.C.E., &c. Price 2s. 6d., post free.

23. **The Construction of Roads and Streets,** with Historical Sketch of the Art of Road-making; and numerous specially-prepared illustrations. By WILLIAM H. MAXWELL, ASSOC.M.INST.C.E., Borough Engineer and Surveyor, Tunbridge Wells. Price 3s. 6d., post free.

24. **Particulars of some Municipal Engineering Works, designed and carried out at Stafford,** by W. BLACKSHAW, ASSOC.M.INST.C.E., M.S.I., Borough Engineer and Surveyor. Paper read before the Incorporated Association of Municipal and County Engineers, at Stafford, June 26, 1897. Price 2s., post free.

25. **Electric Tramway Traction.** By ALBERT D. GREATOREX, ASSOC.MEM.INST.C.E., M.S.A., Borough Engineer and Surveyor, West Bromwich. Price 2s. 6d., post free.

Tramway Rails; Street and other Name Plates; Tree Planting in Streets and other Places. Three short papers (read in connection with THE SURVEYOR Section of the Building Trades Exhibition, 1899). By FRANCIS SMYTHE, Surveyor to the Finchley Urban District Council. The set, price 2d. (post free).

Cremation, by SIR SPENCER WELLS, BART.; **The Smoke Nuisance and How to Remedy It,** by A. E. FLETCHER, Chief Inspector of Alkali, &c., Works, Local Government Board; and **Sanitary Law,** by Prof. A. WYNTER BLYTH. The set, price 3d., post free.

UNIVERSITY OF CALIFORNIA LIBRARY

THIS BOOK IS DUE ON THE LAST DATE
STAMPED BELOW

JUL 30 1914

APR 18 1916

30m-6,'14

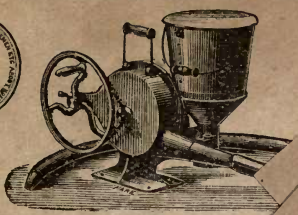
YA 01434

DRAIN TESTING.

To District Councils, Surveyors, Sanitary Inspectors, Drainage Contractors, &c.

WATTS' PATENT "ASPHYXIATOR."

THOUSANDS IN USE.



Under the Patronage of H.R.H. the Prince of Wales,

The War ...rtment and ...ords of the ...dmiralty.

Registered Trade Mark, M...

Certificate of Merit (only award), Sanita... ...lin, 1884.
Certificate of Merit, Sanitary Ex... ...890.
Certificate of Merit, Sanitary Ex... ...1892.

Universally admitted to ... for its efficiency in applyin... TO DRAINS. It is ... for DISIN...E...

95994
TJ651
W8

JOH... & CO.,

...RS,

8 NELSON STREET, BRISTOL.

Also Manufacturers of

IMPROVED SCREW EXPANDING DRAIN STOPPERS,

Specially adapted for use in conjunction with the "Asphyxiator."

DRAIN-CLEARING RODS AND FITTINGS.

Send for Illustrated Catalogue and Testimonials—Post Free.

THE

SEPTIC TANK

SYSTEM

OF

SEWAGE TREATMENT.

No Chemicals. No Sludge.

Low Cost in Construction.

Automatic Throughout.

Nominal Annual Expenditure.

For full Particulars apply to—

THE

SEPTIC TANK SYNDICATE, Ld.,

7 & 8 Bedford Circus, Exeter,

AND

25 Victoria Street, Westminster,

LONDON, S.W.

Gold, Silver, and Bronze Medals, Paris, 1900.

Sanitary Institute of Great Britain: Highest Award, Leeds, 1897.